

Evaluating flood risk governance with geospatial technologies

by

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

Exceptions to sole authorship:

Chapter 2: Minano A., Thistlethwaite J., Henstra D., Scott D. (2021). Governance of flood risk data: A comparative analysis of government and insurance geospatial data for identifying properties at risk of flood. *Computers, Environment and Urban Systems*.

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Chapter 4: Minano A., Thistlethwaite J., Henstra D. (submitted). Evaluating a public-private data-sharing platform for improving flood insurance availability and affordability. *Journal of Regional Environmental Change*.

I hereby declare that I am the lead author for all three manuscripts. I served as principal investigator for all three studies that pertain to this dissertation. I conceptualized the research, collected and analyzed research data, and drafted and submitted the manuscripts to reputable journals. I addressed the comments and feedback from peer-reviewers. My supervisors and collaborator (Scott, Thistlethwaite and Henstra) provided feedback, suggestions and editorial changes.

Abstract

The concept of *governance for flood resilience* has gained traction in scholarship and practice over the last 15 years. *Governance* is distinct from *government* as it recognizes that flood risk management (FRM) is carried out by actors that transcend government and which include the private sector and civil society. Though there is a theoretical notion that effective FRM entails the involvement of a diverse set of actors and measures, there is a notable lack of studies on the development and evaluation of tools designed to foster greater integration between public and private actors to solve FRM problems of common concern.

This dissertation primarily focuses on the Canadian context and the problem of residential properties that are high-risk and “uninsurable” for flood damages, and which are subject of current national public policy discourse. Current public policy discussions revolve around the relocation of these properties away from high-risk flood zones and establishing a public program for extending affordable flood insurance coverage to these higher risk properties. This dissertation focuses on an alternative strategy by evaluating the role that a public-private data-sharing partnership could play in reducing and managing the number of high-risk “uninsurable” properties.

Through three interrelated studies, this dissertation demonstrates how, in the absence of a common approach to flood risk identification, insurers and municipalities have a conflicting understanding of which properties are at risk of flood. The lack of channels for information-exchange between municipalities and insurers are also prohibiting municipal officials from knowing why insurers classify a property as “high-risk”, while also posing difficulties for insurers to become aware of public flood risk mitigation investments happening across Canada. To foster collaboration between insurers and municipal officials for resolving the flood

insurability problem, a data-sharing platform is proposed and evaluated via interviews with municipal officials and insurers. While this process of evaluation confirmed there is a “missing link” between municipalities and insurers, the proposed data platform faces many obstacles for its adoption and evidence gathered suggest it is unlikely to lead to greater availability and affordability of flood insurance products.

Instead, findings support an appeal process that would establish a three-way communication line between insurers, government officials and individual homeowners who are experiencing issues finding affordable flood insurance coverage for their property. This process of appeal would (1) reveal the reasons why insurers classify a specific property as “high risk” of flood, (2) address modelling and technical limitations that may be influencing insurers’ risk classification such as the omission of flood protection infrastructure, (3) agree upon additional measures that could be implemented to reduce physical flood risk by either the homeowner and/or responsible government agencies that could further promote that flood insurance remains available and affordable to the homeowner.

More broadly, this dissertation concludes that in a time of increasing economic losses from floods and climate risk uncertainties, a concerted multi-level government effort is necessary to collect data about flood protection infrastructure. This database can inform the process of appeal but it can also be used to raise awareness and provide confidence among civil society and the private sector about the effectiveness of public infrastructure investments in preventing flood damages. Finally, this dissertation presents novel approaches for evaluating flood risk governance that leverage geospatial data, methods and tools which could be replicated and tested in other international contexts.

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Finally, I would like to thank the Social Sciences and Humanities Research Council of Canada for awarding me a doctoral scholarship and for recognizing my academic merit.

Dedication

To all the women who are not afraid to challenge the status quo.

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List of Abbreviations

| | |
|-------|--|
| FRM | Flood risk management |
| P&C | Property & Casualty |
| IBC | Insurance Bureau of Canada |
| JBA | JBA Risk Management |
| DRP | Disaster Recovery Program |
| G7 | International Group of Seven |
| GFHAs | Government Flood Hazard Areas |
| IFHAs | Insurance Flood Hazard Areas |
| DMTI | DMTI Spatial Inc. |
| FDD | Flood Defence Database |
| A1 | First analysis |
| A2 | Second analysis |
| A3 | Third analysis |
| A4 | Fourth analysis |
| GDP | Gross Domestic Product |
| PREP | Property Resilience and Exposure Program (Australia) |
| ZÜRS | National Flood Hazard Zoning System (Germany) |
| MRAT | Municipal Risk Assessment Tool (Canada) |
| LiDAR | Light Detection and Ranging |
| ABI | Association of British Insurers |
| SOP | Statement of Principles (England) |
| FEMA | Federal Emergency Management Agency (United States) |
| CRS | Community Rating System (United States) |
| RB | Resilience Bridge |

Chapter 1

Introduction to Dissertation

1.1 Research Context

Globally, floods are the most frequently occurring natural disaster and they pose serious social and economic threats (Jha et al., 2012; WHO, 2022). Floods have caused widespread damage in many urban centres where there is concentration of people, infrastructure and economic activities (Bevere & Remondi, 2022; Jha et al., 2012). Between 1996 and 2015, flood risk management (FRM) policies were found to have effectively reduced mortality from floods in many parts of the world, but in the same time period, economic damages caused by flooding have increased substantially (Bevere & Remondi, 2022; CRED & UNISDR, 2016; Jha et al., 2012; Petrucci et al., 2019). This trend of increasing flood losses has been attributed largely to growth of population and economic activities in flood-prone areas (Winsemius et al., 2016). It is anticipated that floods will become increasingly damaging in the future due to socio-economic and climatic change factors affecting many global regions (Bouwer, 2013; Jongman et al., 2012; McClymont et al., 2019).

The strategies and tools used by societies to manage flood risk have changed over time, often in reaction to flood disasters (Surminski & Thielen, 2017). For example, in the early and mid- 20th century, a philosophy of flood control dominated how many countries approached FRM (Costa, 1978; Shrubsole, 2013). During this time, notable flood control structures were built, such as the Hoover Dam in the United States (1931-1936) and Canada's Red River Floodway (1962-1968). In the decades that followed, flood losses continued to climb despite flood control structures (Watt, 1995). As a result, there was a recognition that complementary

strategies were needed, particularly land use and development policies that limit construction on floodplains. Today, there is a recognition that FRM demands a “portfolio of measures” designed to reduce and manage the consequences of floods with varying probabilities and degrees of magnitude (Sayers et al., 2013, p. 55). This FRM portfolio includes measures that prevent flood damages from materializing, such as floodplain development regulations and flood control structures, as well as measures that facilitate flood recovery, such as property insurance (Figure I-1) (National Academies Press, 2013).

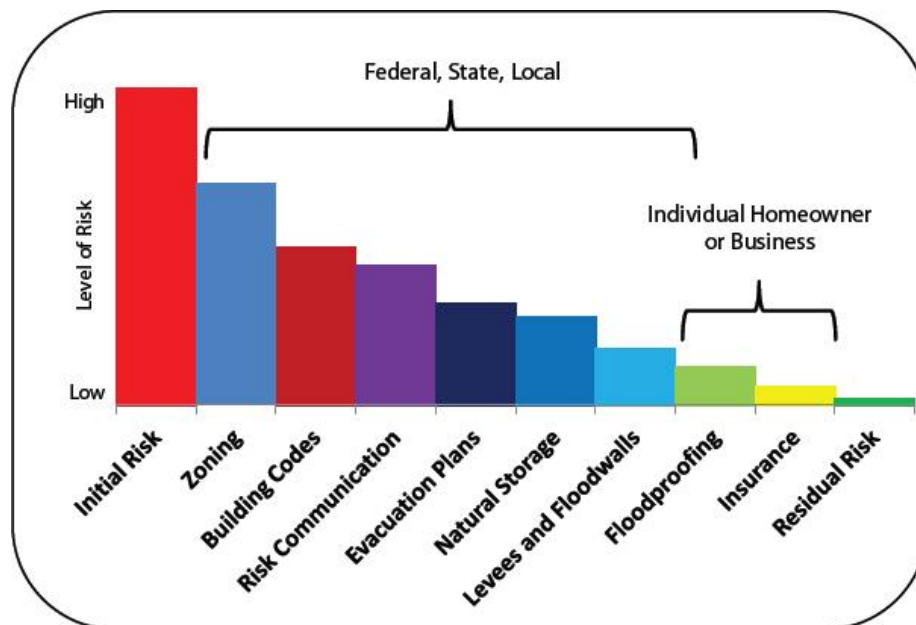


Figure I-1. A portfolio of FRM measures (National Academies Press, 2013)

Increasing flood losses and projected trends facing communities around the world are inspiring new thinking about FRM and how to effectively manage rising economic risks and climate change uncertainty (Alexander et al., 2016a). Notably, scholars are increasingly studying the concept of “governance for flood resilience” (Alexander et al., 2016a; Hegger, Driessen, Wiering, et al., 2016; Morrison et al., 2018, p. 291). *Governance* is distinct from *management*,

where *governance* refers to the “actor networks, rules, resources, discourses and multi-level coordination mechanisms through which FRM is pursued”; while *management* is considered a product of governance (Alexander et al., 2016, p. 39). Put simply, governance focuses on *who* carries out FRM and *how* they do so to achieve the greatest benefits for society in a resource-efficient and legitimate manner (Hegger et al., 2018). *Governance* is also distinct from *government* in that it recognizes that FRM is carried out by actors that transcend traditional government institutions and which may include the private sector and civil society (Alexander, Priest, & Mees, 2016a).

The need for multiple measures and multiple responsible actors to pursue FRM can foster governance fragmentation (Gilissen et al., 2016). In many countries, FRM strategies, such as land use planning, public works, emergency management, and disaster financial recovery, are not a single agency’s responsibility (Golnaraghi et al., 2020b; Kousky & Golnaraghi, 2020; Surminksi, Roezer, et al., 2020). Therefore, flood risk governance is fragmented because there are multiple agencies simultaneously working on specific aspects of FRM, such as municipalities who are responsible for enforcing floodplain regulations, and insurance companies who are responsible for financing flood recovery. Although governance fragmentation is not a problem *per se*, scholars assert fragmentation can lead to difficulties such as information asymmetry and actors working at cross-purposes, which “can prove detrimental to the effectiveness of FRM” (Gilissen et al., 2016, p. 12). To foster governance interconnectedness, new processes may need to be established, such as through inter-organizational data-transfer, defining shared goals and establishing joint policies and terms for cross-sector collaboration (Gilissen et al., 2016).

Flood risk governance integration research is in its infancy. One recent review, for instance, found that “research supporting the governance of FRM for resilience lacks integration,

and methods of mitigating this lack of integration are poorly studied” (Morrison et al., 2018, p. 291). This gap is evidenced through the lack of studies, tools and methodologies that integrate physical and social dimensions of FRM, top-down and bottom-up governance approaches, and research, policy and practitioner communities (McClymont et al., 2019; Morrison et al., 2018). It is anticipated that by integrating these dimensions, such as through tools, “more rapid advances in our understanding of linked physical and social influences on flood risk and improved FRM governance” will occur (Morrison et al., 2018, p. 300). This dissertation contributes to this knowledge gap by evaluating the need for flood risk governance integration tools in Canada, developing a tool that fosters governance integration, and evaluating whether such a tool is appropriate, feasible and effective for strengthening societal flood resilience in the Canadian context.

1.2 Canadian Context

FRM has traditionally been dominated by local, provincial and federal government agencies that oversee programs ranging from floodplain delineation, flood damage prevention, emergency management and disaster recovery (Shrubsole, 2013). In particular, governments have been largely responsible for funding flood recovery through federal and provincial disaster assistance programs. In the last 10 years, the cost of these programs has increased to the point where many consider it no longer economically or socially sustainable (PBO, 2016). In response, governments started to support the expansion of the availability of overland flood insurance through private insurers (P. S. Canada, 2018). This represents a considerable shift in Canada’s approach to FRM whereby the property and casualty (P&C) insurance industry has emerged as a prominent voice in FRM policy (IBC, 2019). The P&C industry became a more important stakeholder group in FRM following the launch of residential flood insurance products in 2015

(Calamai & Minano, 2017). The increased importance of the P&C industry in FRM has created a new set of benefits, such as a new option for financial self-protection, as well as challenges, such as the opaque relationship between flood insurance policies and public disaster assistance programs.

With regards to FRM, insurers largely work in parallel from governments. For example, insurers are known to use flood hazard datasets to identify and price flood risk that differ from those data accessible to government agencies (Calamai & Minano, 2017). Since many insurance companies operate at a national scale, there has been a surge of national flood models since 2014 designed to support flood insurance product development, pricing and underwriting decisions (JBA, 2020). When this doctoral research began in 2018, little was publicly known about the nature of these flood models and whether and how these models may be producing contradictory views of flood risk than those accepted by government agencies. The need for the P&C industry to have a consistent national dataset of flood hazard areas also gave rise to criticisms about the way flood hazard data was being collected in Canada, particularly since flood hazard data had been collected in a sporadic and inconsistent fashion by multiple governmental agencies (Henstra et al., 2019).

Having a different set of flood risk data to inform underwriting and pricing is not a problem *per se*. However, a lack of transparency about why insurers consider certain properties as “high risk” of flood is a challenge for public policy. Specifically, the Government of Canada launched working groups and task forces in 2018 and 2020 to find solutions “to protect homeowners at high risk of flooding and without adequate insurance protection” (P. S. Canada, 2020; IBC, 2019; PSC, 2020, para. 2). The Insurance Bureau of Canada (IBC) asserts that 6-10% of Canada’s housing stock is at high-risk of flood and flood insurance for these properties is

either unavailable or unaffordable (Al-Shibeeb, 2022; IBC, 2019). Multi-sectoral working groups have discussed several measures to deal with high-risk properties, ranging from property relocation to establishing a Crown corporation to provide flood insurance coverage to high-risk properties (Public Safety Canada, 2022). Nevertheless, a gap in insurability persists and insurance industry representatives expect the number of high-risk properties to escalate “as we build more homes in floodplains. And as flooding becomes more severe given climate change.” (Al-Shibeeb, 2022, para. 8).

In parallel to public policy discussions about high-risk “uninsurable” properties, government agencies at all levels have made investments to improve flood risk identification (e.g., update local flood studies) and flood protection infrastructure. For example, the National Disaster Mitigation Program (NDMP) allocated \$200 million over 2015 and 2020 for “advancing work to facilitate private residential insurance for overland flooding” (P. S. Canada, 2018, para. 3). The NDMP has been renewed to allocate additional funds to advance flood risk analysis, flood hazard mapping, mitigation planning and structural mitigation projects. This federal initiative is supplemented by other federal funds, such as the Disaster Mitigation and Adaptation Fund¹, and efforts carried out by sub-national government agencies, such as municipalities, conservation authorities, and provincial bodies (Infrastructure Canada, 2018). It is unclear, however, whether these infrastructure investments and improvements in flood risk identification

¹ The Disaster Mitigation and Adaptation Fund was launched in 2018 by the Government of Canada to invest \$2 billion over 10 years in structural and non-structural infrastructure projects to mitigate the impacts of natural hazards and climate change (I. Canada, 2018)

have reduced the number of high-risk “uninsurable” properties, and the specific factors that are perpetuating this problem across different Canadian regions.

1.3 Research Objectives

The overarching goal of this research was to advance flood risk governance evaluation processes by leveraging geospatial data, methods, and technologies. The specific goal of this research was to evaluate the strengths and weaknesses of Canada’s governance approach to FRM and identify pathways that enable intersectoral collaboration for increasing societal resilience to floods. This research explored the idea of cross-sector data-sharing to enable new forms of public-private collaboration to alleviate the issue of high-risk “uninsurable” properties. To this end, three interrelated studies were conducted, each with its own research questions and objectives:

1. **Study #1:** How similar are insurer and government views of flood risk? What are the potential societal implications of divergence in these views of flood risk?
 - a. **Objective 1:** Map, quantify and compare flood-prone regions and properties by leveraging geospatial data used by government agencies and insurance companies for flood risk identification in three Canadian cities (Halifax, Toronto, and Calgary).
 - b. **Objective 2:** Based on the results of *Objective 1*, discuss the implications that conflicting views of flood risk could have for addressing flood insurance unavailability and unaffordability issues in Canada.
2. **Study #2:** Is there an appetite among municipalities and insurance companies to integrate their flood risk data into a shared data platform to inform FRM efforts and decisions?

What should a data integration platform do to reflect the interests of municipal officials and insurance representatives?

- a. Objective 1: Survey Canadian municipal officials to assess the extent to which they have access to flood insurance data (e.g., industry flood hazard data, properties at high-risk of flood identified by insurers).
 - b. Objective 2: Survey P&C insurance companies with Canadian operations to assess their level of interest to share their flood risk insights and company data with government agencies.
 - c. Objective 3: Evaluate whether a data platform that integrates public and private flood risk data is of interest to municipal officials and insurance representatives to inform FRM efforts.
3. **Study #3**: Does the fragmented governance approach to flood risk management create barriers for alleviating problems of flood insurance availability and affordability in Canada? Is a data platform an appropriate, feasible and effective tool to improve and sustain the availability and affordability of flood insurance in Canada? Are there more effective alternatives than a data platform to improve the availability and affordability of flood insurance in Canada?
- a. Objective 1: Develop a data platform prototype that captures the interests of municipal officials and insurance companies reported in *Study #2*.
 - b. Objective 2: Interview municipal officials and insurance representatives to evaluate the data platform and assess whether they would share data with the other sector via this platform and identify foreseeable effects of cross-sector data-sharing.

- c. Objective 3: Analyze the interview data and determine if a data platform is an appropriate, feasible and effective tool to improve the availability and affordability of flood insurance in Canada.

1.4 Outline of Dissertation

This dissertation is written in a manuscript-style format composed of five chapters. **Chapter 1** provides an overview of flood risk governance literature and describes how the proposed research agenda addresses literature gaps identified by international scholars.

The body of this dissertation is divided into three chapters (Chapters 2, 3 and 4). Each of these chapters presents its own set of research questions, literature review, methodology and results, but they are conceptually aligned and build upon one another. **Chapter 2** is published in the journal *Computers, Environment and Urban Systems* and focuses on a comparative flood exposure analysis by using flood hazard data used by governments and insurers to inform their FRM decisions. The study results show large differences between flood hazard areas used by governments and insurers alike which informs a discussion on the *potential* implications that contrasting views of the same problem can have for building flood resilience.

Chapter 3 is under review in the *International Journal of Disaster Risk Reduction* and it builds upon findings of Chapter 2 and leverages the principles of effective flood risk governance to create a conceptual data-sharing and integration platform that could be used by local governments and insurers to exchange flood risk data. A survey was administered to municipalities across Canada and to P&C insurers to discern the level of interest in this conceptual idea and explore the viability of this concept in practice.

Chapter 4 was submitted to *Journal of Regional Environmental Change*. This Chapter builds upon findings of Chapter 2 and Chapter 3 and presents a prototype of a data-sharing platform, labelled the “Resilience Bridge Platform”. Public and private stakeholders evaluated the Resilience Bridge Platform based on its scope, feasibility, and effectiveness as a tool for fostering interconnections in flood risk governance for overcoming issues with high-risk “uninsurable” properties. **Chapter 5** summarizes the research findings, including their implication for flood risk governance literature, and presents an agenda for future research.

Chapter 2

Governance of flood risk data: a comparative analysis of government and insurance geospatial data for identifying properties at risk of flood

Minano, A., Thistlethwaite, J., Henstra, D., Scott, D. (2021) Governance of flood risk data: a comparative analysis of government and insurance geospatial data for identifying properties at risk of flood. *Computers, Environment and Urban Systems*, 88: 101636.

Flood risk maps are essential sources of information for flood risk management (FRM) decisions. Commercial flood models used by the insurance industry are rarely studied in the academic literature which has led to difficulties in understanding their sources of uncertainty and opportunities for improvement. This paper compares regions and residential properties identified as exposed to floods by an insurance industry model and by government authorities responsible for FRM in three Canadian cities. Findings show that the insurance model is identifying substantially greater number of regions and properties as at-risk of flood, and little overlap exists between public and private flood maps. The paper discusses opportunities for data integration and increased data transparency for supporting flood resiliency efforts in Canada.

2.1 Introduction

At a global scale, the number of flood events and their economic impacts have increased substantially over the past decades (CRED & UNISDR, 2016; Jha et al., 2012; Winsemius et al., 2016). Economic damages from floods are expected to continue rising in the future driven by growth of population and economic activities in flood-prone areas (Bouwer, 2013; Winsemius et al., 2016). Additionally, models indicate that climate change will likely increase the frequency of heavy precipitation events in many regions, which can create more opportunities for flooding (IPCC, 2014; Kundzewicz et al., 2014). Risks created by floods are not going unnoticed by scholars and practitioners which has fuelled initiatives for improving the effectiveness of flood risk management (FRM)(Alexander et al., 2016b).

There is broad acceptance in the literature that flood insurance is an effective mechanism for financing flood recovery (W. J. W. Botzen & van den Bergh, 2008; Hegger, Driessen, Wiering, et al., 2016). Flood insurance can provide multiple benefits to society, including greater certainty of financial compensation in the event of a loss, swifter reconstruction in the aftermath of a flood, and incentives for community and personal flood risk reduction (W. J. W. Botzen & van den Bergh, 2008; Surminski & Thielen, 2017). Although appealing in principle, an insurance scheme with these characteristics is complex to implement and it often requires the involvement of government (Atreya et al., 2015). Internationally, governments have supported flood insurance schemes in various ways to promote high insurance penetration and increase the availability and affordability of flood insurance in higher risk areas (Dufty et al., 2020; Kousky & Golnaraghi, 2020; Surminski & Eldridge, 2017).

In Canada, the federal government has announced that it will develop a national flood insurance program which will target “homeowners at high risk of flooding and without adequate

insurance protection” (Office of the Prime Minister, 2021). FRM has a long-history in Canada, but it has largely been the responsibility of provincial, territorial and local governments (Shrubsole, 2013). As a consequence, data on FRM has not historically been collated by the federal government which poses challenges for clearly understanding what and who is at-risk of flooding across the country (Henstra et al., 2019; Minerva Intelligence, 2020). For those external to the industry, access to data on flood insurance is largely limited to high-level statistics on insurance penetration and insured losses. The presence of data silos can impede policy progress on a national flood insurance scheme, since it is difficult to locate high-risk properties and determine why they may not have adequate flood insurance protection (e.g., personal choice vs. insurers refused flood coverage).

Challenges to access data on flood insurance are not unique to Canada. In other countries, insurers have expressed reluctance to share their data, including flood modelling data used for pricing premiums, citing conflicts with their business interests (e.g., losing market competitiveness) (O’Hare et al., 2016; Surminksi, Mehryar, et al., 2020). However, there are increasing discussions about data-sharing across sectors for gaining a deeper understanding about current limitations with flood insurance and (co-)developing targeted solutions to solve problems that are of mutual interest (CWN & IBC, 2019; Surminski, 2017a).

This research leverages floodplain data used by local and provincial governments in Canada for FRM purposes (e.g., public risk awareness, property buy-outs, land use planning). This analysis compares floodplain data created by governments with floodplain data created by JBA Risk Management (JBA). JBA licenses their data to insurance companies for pricing flood insurance products available in Canada (JBA, 2020). The intention of this analysis is to (1) shed light on where uninsurable, high-risk residential properties may be located, and (2) identify

policy and research opportunities that arise by integrating public and private data silos. The paper concludes with a discussion on how data silos are creating opaqueness about current residential exposure and vulnerability to floods which can hinder the development of programs that tackle existing issues with the residential flood insurance market.

2.2 Insurance for flood resilience

The concept of “governance for flood resilience” has gained momentum in the academic literature over the last few decades as scholars seek avenues to increase resilience by strengthening society’s capacity to prevent and mitigate risks, recover from and adapt to floods in a changing climate (Alexander et al., 2016; Morrison et al., 2018, p. 291). In principle, *effective flood risk governance* is composed of multiple FRM strategies and leverages the collective expertise and capabilities of public and private actors (Driessen et al., 2018). It is understood that integrating the efforts of multiple actors involved in FRM will increase resilience to floods because multiple lines of defence are created and risks can be managed more effectively than in the past. Indeed, in countries with long histories of managing floods, responsibilities for FRM are spread among many public and private actors (e.g., municipalities, financial institutions, property owners), which allows for building flood resilience through multiple strategies (e.g., restricting development on floodplains, requiring proof of flood insurance for mortgage lending) (Gilissen et al., 2016; Hegger, Driessen, & Bakker, 2016).

It is perhaps unsurprising that international bodies like the United Nations are calling for global action to “strengthen disaster risk governance to manage disaster risk”, including the need to “promote mechanisms for disaster risk transfer and insurance...in order to reduce the financial impact of disasters on Governments and societies” (UNISDR, 2015, p. 19). Flood insurance is

widely cited in both disaster risk reduction and climate adaptation literature as an effective risk transfer mechanism that can facilitate financial recovery from floods (W. J. W. Botzen & van den Bergh, 2008; Surminski & Oramas-Dorta, 2014). By collecting premiums, insurance companies have a contractual obligation to their policyholders to provide financial compensation in the event of a loss. This arrangement can lead to multiple benefits for society and governments because it can provide private property owners with “certainty about post disaster support, [and]...faster and more efficient reconstruction” while also reducing dependence on government disaster assistance (Surminski and Thieken, 2017, p. 980).

Although flood insurance is considered to be an effective risk transfer mechanism, there are many viewpoints regarding its implications for broader flood resilience objectives, predominantly its relationship with *risk reduction* (Surminski & Oramas-Dorta, 2014). Some argue flood insurance can incentivize flood risk reduction because it sets a market price for risky behaviour; therefore, those who have higher premiums can feel incentivized to mitigate their risk in order to reduce their premium (Kunreuther, 1996). Others assert that flood insurance creates a moral hazard, whereby “policyholders’ [have a] low willingness to implement risk-reduction measures or even relocate out of flood-prone areas expecting insurance payouts” (Hanger et al., 2018, p. 981). From this perspective, insurance facilitates a cycle of repeat loss and recovery as insurance is designed to restore damaged properties to pre-disaster conditions, rather than paying for property upgrades or relocation that could limit the impacts of future floods.

In reality, the effectiveness of flood insurance as a risk transfer mechanism and as a risk reduction driver can be hindered by several factors. First, in many countries where flood insurance is available, consumer uptake of this product is low (Surminksi, Roezer, et al., 2020). One reason is that flood coverage is often an optional add-on to standard home insurance policies

that is not sought out or perceived as necessary coverage by property owners. This can also be the case for homeowners who are unaware of their property's flood risk (Kunreuther, 1996). Additionally, insurers may assess that a property's risk is unacceptably high and refuse to offer protection for flood altogether (O'Hare et al., 2016); thereby leaving those most exposed to flood damages to seek other means of financial protection (e.g., self-insurance, government disaster assistance). Low insurance penetration undermines flood insurance as an effective risk transfer mechanism leaving other actors responsible and possibly unprepared for financing disaster recovery.

Empirical research has also found weak evidence that flood insurance is an incentive for risk reduction, particularly for household-level risk reduction (Atreya et al., 2015; Surminski & Eldridge, 2017; Surminski & Oramas-Dorta, 2014). First, the effectiveness of flood insurance as a risk awareness tool has been questioned because “insurers usually do not differentiate or disclose to their customers the percentage relating to flood insurance” (Surminski and Thieken, 2017, p. 993). Insurers have also been found to offer few incentives for the implementation of household flood risk reduction measures (e.g., premium discounts, risk reduction information) (Hanger et al., 2018; J. E. Lamond et al., 2009). Studies have indicated that this is because “the insurance industry remains doubtful that property level resilience and resistance measures provide a foundation for lowering policy costs or excesses” (Surminski and Eldridge, 2017, p. 422).

In short, flood insurance can theoretically be an effective tool for enhancing flood resilience and fostering a culture of preparedness, but empirical research shows that it often struggles to achieve its full potential, whether due to low insurance uptake or an unclear connection with broader flood resilience objectives.

2.2.1 The role of government in flood insurance schemes



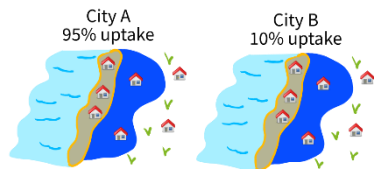
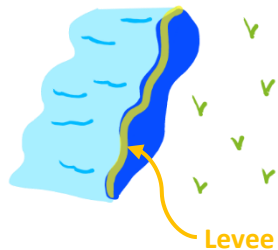

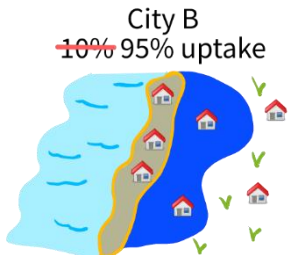
Internationally, governments have played active roles in support of flood insurance schemes (Atreya et al., 2015). Their involvement has been instrumental to address market imperfections that are difficult for the private sector to solve on its own. Government intervention has involved, for instance, developing an insurance solution for high-risk households (e.g., U.S.), promoting flood insurance penetration through public awareness campaigns (e.g., Germany), legislating standard home buildings and contents insurance policies to include flood coverage (e.g., Australia), and committing to risk reduction in exchange of increased insurance availability (e.g., England) (Mason, 2011; National Academies Press, 2015; Surminksi, Roezer, et al., 2020). Although the specific role that governments play in flood insurance schemes varies from country to country, they have been instrumental for addressing observed limitations with how the private market is operating.

One initiative to strengthen flood insurance markets that has gained momentum in recent decades is the cooperation of the public and private sectors in data management (CWN & IBC, 2019; Surminksi, 2017a). There are some recent examples of this type of public-private cooperation that are being designed to increase the industry's capacity to detect and assess flood risks accurately, which, as a result, are leading to a re-evaluation of property-level flood risk. For example, the German Insurance Association's nationwide flood hazard zoning system (ZÜRS) began to integrate more sophisticated maps created by public water authorities in response to technical limitations of its original flood maps. This effort reportedly reduced the proportion of high-risk properties in Germany from "1.5% of all buildings in 2008 to 0.65% of all buildings in 2016", effectively reclassifying 67,000 homes to lower risk zones (Surminksi and Thieken, 2017, p. 989). Similarly, in Australia, local governments can contribute data (e.g., local flood hazard

studies) to the insurance industry's National Flood Information Database in order to increase the precision of the industry's flood risk assessments, which can in turn reduce premiums where risk has been re-evaluated (Floodplain Management Australia, 2015; Insurance Council of Australia, 2021). By providing access to local flood mapping studies and technical data, governments are enabling the insurance industry to more precisely detect property-level flood risk and reflect that in their pricing.

In addition to supporting the insurance industry's technical ability to detect risk, public-private cooperation in data management is becoming topical for the benefits that it can also bring to governments, and for strengthening the relationship between flood risk reduction and flood insurance (Table II-1)(Surminski, 2017b). For example, municipalities in Canada assert that access to insurance flood hazard maps could "support [risk] mitigation efforts and enable them to focus their efforts more appropriately and, in some cases, help them identify higher-risk areas that were not previously known" (CWN, 2020, p. 15). If municipal governments know their investments in risk reduction will be acknowledged by insurers, this arrangement could incentivize governments to invest in flood risk reduction on an ongoing and long-term basis as they could see immediate benefits through tangible indicators (e.g., increases in flood insurance availability in Year A vs. Year B in their jurisdiction). Such an arrangement could encourage an important departure from the "status quo" in disaster risk management that tends to review practices in reaction to disasters (Surminski & Thieken, 2017; UNISDR, 2015a).

Table II-1. Conceptual scenarios of how public-private data management can strengthen flood resilience. The diagrams depict rivers in light blue, floodplain area in dark blue, high risk area in red and moderate risk area in orange.

| Conceptual scenarios | | | |
|--|--|---|---|
| | Scenario 1: Insurers provide* flood hazard modelling data | Scenario 2: Insurers provide* data on residential flood exposure | Scenario 3: Insurers provide* data on flood insurance uptake |
| Data that insurers provide* to governments | <p>The insurance industry's model uses a rough hydraulic modelling approach and does not account for flood defences.</p>  | <p>The insurance industry shares with government where high-risk, uninsurable properties are located.</p>  | <p>The insurance industry shares with municipal governments what the uptake of flood insurance is in and outside a commonly recognized floodplain.</p>  |
| Response from government to receiving insurance data | <p>Governments supply local flood studies, flood protection infrastructure data and other technical data (e.g., Digital Elevation Models) for enhancing the industry's model.</p> | <p>Governments target risk mitigation efforts in highly exposed areas and communicates this to the insurance industry via a common database.</p> | <p>Governments recruit researchers to explore why flood insurance penetration is higher in some communities and not others (e.g., social, psychological, institutional factors).</p> |
| Impact of public-private collaboration in data management | <p>This collaboration addresses assumptions of the industry's models and improves the detection and prediction of flood hazards.</p>  | <p>The industry re-evaluates risk assessments for areas benefited by new government risk reduction projects.</p>  | <p>Research evidence informs policies and programs for supporting at-risk and underinsured populations.</p>  |

| | | | |
|---|--|---|--|
| Impact of public-private collaboration on flood resilience | This leads to a reduction of modelled flood-prone areas due to improvements in input model data. | This leads to a reduction in premiums in protected areas and makes insurance more affordable. | The implementation of policy interventions leads to increases in flood insurance uptake among at-risk populations. |
|---|--|---|--|

*The term “provide” here does not necessarily mean that insurers provide raw data to governments.

Insurers can also provide a view of their data through a Web mapping service that is accessible by governments, or provide processed data (e.g., summary statistics for metrics of interest).

Despite some work in this space (e.g., Thistlethwaite et al., 2018), there is a lack of empirical research that showcases the data that is available or created by the insurance industry for assessing and pricing flood risks. As documented in international literature, the insurance industry has historically been reluctant to release their data because they feared harm to their commercial interests (e.g., losing market competitiveness, data protection conventions) (O’Hare et al., 2016; Surminski, 2017b). However, increasing transparency about the industry’s data could facilitate a greater understanding about what these data can offer other sectors involved in FRM. Furthermore, integrating public and private data sources in a data management system could increase transparency and awareness about how each sector is contributing to FRM and directing collaborative responses for existing and emerging problems.

2.2.2 Flood insurance in Canada

The Canadian federal government has committed to developing a national flood insurance program for Canada (Office of the Prime Minister, 2021). There are few documents as of yet that

have been published about what the program will achieve and how the federal government and other sectors will be involved in its implementation. To date, it has been announced that this will be a low-cost flood insurance program that will target “homeowners at high risk of flooding and without adequate insurance protection” (Office of the Prime Minister, 2021). In 2021, a Task Force on Flood Insurance and Relocation was established with a mandate to examine options for developing this insurance program, and to also design a plan for assisting the relocation for properties at “highest risk of recurrent flooding” (PSC, 2020).

The interest in flood insurance has been growing in Canada since the Alberta floods in 2013, and it is a deviation from traditional financial disaster recovery processes that have been the responsibility of the federal and provincial governments (Bruce, 1976; Calamai & Minano, 2017). Existing government disaster recovery programs (DRP) are designed to pay for uninsurable losses (public or private) when large disasters occur and generally finance essential repairs (Alberta Government, 2021a; EMO Nova Scotia, 2021; Government of Ontario, 2020). DRP can also pay for ones losses when insurance coverage is insufficient to cover for essential repairs (e.g., Ontario) (Government of Ontario, 2020).

Until 2015, Canada was the only G7 state in which overland flood insurance was unavailable for residential properties (Calamai & Minano, 2017). This product is not yet “readily and reasonably available” to all Canadians and damages incurred from floods could still be covered by DRP (Alberta Government, 2021b). As of 2019, the Insurance Bureau of Canada (IBC) estimated that “about 34% of Canadians are now insured for overland flood risk” and 16 companies are offering residential flood products (IBC, 2019, p. 16). This coverage is purchased on a voluntary basis (Golnaraghi et al., 2020b). Additionally, IBC estimates that approximately 7-9% of the Canadian housing stock falls in a high-risk category and would experience

difficulties finding affordable flood insurance, ranging from 800,000 to 1 million households (IBC, 2019). The insurance industry in Canada is politically engaged in this subject and has invested in many related activities, including the development of a national flood hazard map in 2014—an initiative led by IBC in collaboration with flood modelling firm JBA—as a way to support insurance companies in offering residential flood insurance for the first time in Canada (Calamai & Minano, 2017; IBC, 2019).

Residential flood insurance in Canada is not subject to the same regulatory treatment and government oversight as other types of insurance (e.g., auto insurance)(Golnaraghi et al., 2020b; Kovacs & Kunreuther, 2001). Insurance companies can independently design flood insurance products and are not required to disclose where they do not offer flood insurance coverage due to high risk levels. Aside from IBC’s high-level reporting on the state of the flood insurance market, other sectors (e.g., government, academia) can license data from CatIQ, an organization that collates data from the industry on their exposure to various perils, including flood. These data, however, are aggregated at a postal district level (i.e., Forward Sortation Area) (CatIQ, 2020). To put this into perspective, an average postal district encompasses 8,000 households (ranging upwards to 60,000 households) and can represent a large geographic area, particularly in rural Canada (SFU, 2020). This is a sufficient level of granularity to gain some market insights on all households, but not specifically for flood-exposed households as these tend to spatially concentrate in areas within a postal district (e.g., along river banks) (Insurance Council of Australia, 2011).

This knowledge gap presents a challenge for the Government of Canada, as it is difficult to know where the *high-risk households who do not have adequate flood insurance protection* are located across the country and why they do not have this coverage (e.g., lack of interest in

flood insurance vs. high cost of flood insurance coverage). To make matters more difficult for identifying national residential flood exposure, government-issued flood maps are currently not curated in a single national database (Henstra et al., 2019). Addressing this knowledge gap could provide the information needed to prioritize key issues for action, and to clarify the federal government's role in addressing such issues through a national flood insurance program.

2.3 Study objectives and study area

This study compares residential flood exposure as identified through floodplain datasets used by governments for FRM purposes (e.g., land use planning, public risk awareness, property buy-outs) to those used by insurance companies for pricing flood insurance products. Since data on flood insurance is scarce for sectors outside the industry, this study's objective is to increase transparency about what insurance companies know about residential flood exposure, and to detect which properties may fall under a high-risk category and experience difficulties finding affordable flood insurance coverage. The intention for comparing insurance and government floodplains is to also detect opportunities for strengthening the alignment between government FRM efforts and the private flood insurance market, such as the relationship between risk reduction and decreases in high-risk, uninsurable households. This research is timely because findings could have implications for policymakers designing Canada's national flood insurance program.

This study focuses on three Canadian cities: Toronto (Ontario), Halifax (Nova Scotia) and Calgary (Alberta). These three cities were selected in order to account for their unique local approaches to FRM. Being aware of the broader institutional context could help detect opportunities for aligning public and private FRM efforts (Morrison et al., 2018).

2.4 Data and methodology

This study leverages three main data sources to calculate residential flood exposure. First, government flood hazard areas (GFHAs) were acquired for each city. Second, insurance flood hazard areas (IFHAs) for the three cities were extracted from JBA's 2018 Canada Flood Map product, which contains flood hazard data for multiple modelled flood events (e.g., 20-, 100-, 200-year floods) at a national scale. Third, 2018 residential housing stock data for the three cities was licensed from DMTI Spatial Inc., a leading producer of location intelligence, which maintains a database of all addresses in Canada, including address locations and address attributes (e.g., postal code, city) for more than 15 million addresses. While some of the GFHAs were available for free download via government Open Data portals, the researchers entered various data sharing agreements with government entities, JBA and DMTI to gain access to the data used for this research.

This study focused on *fluvial* flood hazards because data for other types of flood hazards (e.g., coastal, urban flooding) is much more limited in Canada, especially from government sources (Henstra et al., 2019). Canada also has a long legacy of managing fluvial floods using floodplain maps, and the impact of floodplain regulations is evident in how cities have grown for the last 50 years (Watt, 1995).

In the absence of an official definition of a "high risk property", this study used the *100-year floodplain* as a way to separate higher risk properties from the rest of the housing stock. The 100-year flood has been used as a minimum national standard for floodplain mapping and floodplain regulations since the 1970s and IBC also considers it as a conservative measure for categorizing properties as high-risk (IBC, 2019; Watt, 1995).

2.4.1 Data sources

Government flood hazard areas (GFHAs)

In all three cities, the GFHAs inform government FRM decisions, including actions that prevent the construction of new high-risk properties and reduce risks faced by properties already built on floodplains. These floodplain lines at a minimum are based on a 100-year flood event, with the exception of Toronto where floodplain maps are based on the “greater of the Hurricane Hazel storm event or the 100-year storm event” (TRCA, 2014, p. 91). Maps showing these floodplain boundaries are available for the public to look up their individual address and flood exposure (City of Calgary, 2020a; Halifax Regional Municipality, 2020; TRCA, 2019). Arguably, these public maps are the only legitimate and “official” source of information to determine personal flood risk in these three cities.

Although the GFHAs are used for floodplain regulatory purposes in all three cities, there are some distinctions on the policies that reference these maps. In both Calgary and Halifax, there are portions within the floodplain (labelled “floodway”), where flooding is more likely to occur and/or cause severe damage, that have stricter land use restrictions than the remainder of the floodplain (labelled “flood fringe”) (Alberta WaterPortal Society, 2014; HRM, 2021). New residential development is restricted on the floodway, but some non-residential land uses may still be allowed on the floodway, such as agriculture and parkland. The floodway area in Calgary was also used to detect eligible properties for buy-outs following the 2013 Alberta floods (Government of Alberta, 2013). In Calgary and Halifax, residential development is allowed on the flood fringe under certain conditions (e.g., raised foundations above a specified flood level) (City of Calgary, 2021a; HRM, 2020). In Toronto, all new residential development is prohibited

on the entire floodplain, but historical communities exist in parts of the floodplain (TRCA, 2014). Therefore, it is expected that there will be some residential properties in GFHAs because these may be historical buildings that pre-date floodplain regulations or newer properties that have been floodproofed.

In addition to regulatory floodplains, there are some informational flood hazard datasets that were also included for this analysis that were created in 2015 and 2017 for Calgary and Halifax, respectively. In Halifax, these maps account for climate change, and the city is considering updating its regulatory floodplain area based on this new information (HRM, 2021). This area is larger than HRM's current regulatory floodplain (HRM, 2021). The City of Calgary uses the new floodplain study for providing building design recommendations that exceed floodplain regulations (City of Calgary, 2020b). It was important to account for both regulatory and informational flood maps for this analysis to have a comprehensive view of areas that are prioritized for flood risk prevention and risk reduction by governments (Figure II-1).

| Government flood hazard areas (GFHAs) | | |
|---|---|--|
| For each city, the GFHA is the maximum spatial extent of all government floodplain datasets | | |
| Calgary | Halifax | Toronto |
| Floodplain dataset #1: Regulatory floodplain Source: Alberta Government | Floodplain dataset #1: Regulatory floodplain Source: Halifax Regional Municipality | Floodplain dataset #1: Regulatory floodplain Source: Toronto and Region Conservation Authority |
| Floodway Flood fringe | Floodway | Floodplain |
| 100-yr RP | 20-year RP | The greater of Hurricane Hazel (350-yr RP) or 100-yr RP |
| Floodplain dataset #2: Informational floodplain Source: City of Calgary | Floodplain dataset #2: Recommended floodplain Source: Halifax Regional Municipality | |
| Flood hazard area | Flood hazard area (accounting for future climate change) | |
| 100-yr RP | 100-yr RP | |

Figure II-1. Summary of government flood hazard areas used for this study. Datasets last accessed on February 2021 (Halifax); May 2019 (Toronto); and February 2021 (Calgary). RP = Return period. Halifax’s recommended floodplain covers a larger area than the regulatory floodplain.

Insurance flood hazard areas (IFHAs)

This study used JBA’s 2018 Canada Flood Map to extract flood hazard data for the three cities.

JBA is a well-established flood risk modelling firm that supplies data to IBC and insurance companies in Canada and internationally (IBC, 2019; Surminski, 2017a). JBA affirms that its

“Canada Flood Map is the most widely used map in the Canadian re/insurance market” (JBA, 2020, p. 1).

JBA produces several spatial data products that depict *undefended* flood zones for different flood return periods (e.g., 20-, 100-, 200-year floods). For comparing with the GFHAs that at a minimum represent a 100-year flood event, this study used JBA’s 100-year return period flood layer. JBA’s 100-year flood layer provides information on the spatial extent and flood water depths for a modelled 100-year flood event. It is expected that where the GFHA represents a more severe event than the 100-year flood (e.g., Toronto), the GFHA will be cover a larger area than the IFHA.

JBA’s flood hazard model does not account for the presence of flood defences, such as dikes and levees. However, it has created an additional dataset that does capture known or assumed defences. JBA’s Flood Defence Database (FDD) depicts areas across Canada that are protected from fluvial floods, including information about the standard of protection of a defence structure (e.g., the defence protects properties from a 100-year flood). The FDD was used to identify properties that are exposed to floods but have some level of protection according to JBA.

Residential address database

To identify residential flood exposure, this analysis used a 2018 residential address dataset containing 933,468 residential addresses across the three cities (Table II-2). This dataset includes address location and characteristics for each of the 933,468 residential addresses, such as municipality, province, postal code, primary use of the address (e.g., residential), and whether the address corresponds to a multiple dwelling unit (e.g., apartment buildings). Although

condominiums are included in this address dataset, only the addresses for single-dwelling units were selected for this analysis since these could be directly damaged by a flood.

Table II-2. Number of properties in study area

| City | Total number of addresses | Number of residential addresses (single-dwelling) |
|--------------|----------------------------------|--|
| Calgary | 559,227 | 347,901 |
| Halifax | 192,563 | 117,657 |
| Toronto | 1,285,807 | 467,910 |
| Total | 2,037,597 | 933,468 |

2.4.2 Methodology

Detecting flood-prone residential properties

A standard Geographic Information System software (i.e., ArcGIS) was used to spatially detect whether each address point was located in a GFHA, IFHA or neither flood zone (Figure II-2). If a property was located in any of the flood zones, it was classified with a 1, otherwise it was classified as a 0. This binary classification allowed for detecting how many properties were located *only* in GFHAs, *only* in IFHAs, *both* in GFHAs and IFHAs, and those that were outside of any flood zone. This process was repeated for each of the 933,468 properties in the study area.

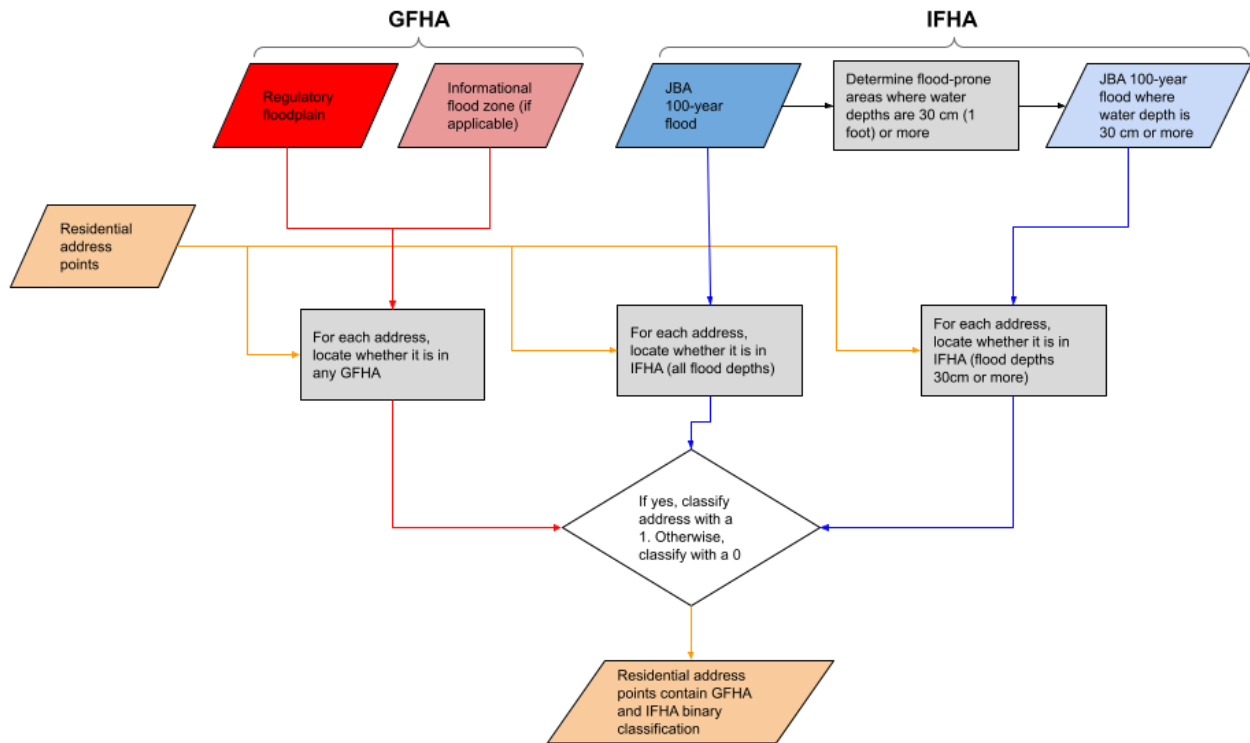


Figure II-2. Datasets used for classifying properties as at-risk of flood

The properties were classified using four different methods for assessing property-level flood risk, which ranged from strict to lenient methodological approaches for classifying a property as at-risk of flood (Figure II-3). The first analysis (A1) used the address point locations to assess whether each point was located in a GFHA, as well as an IFHA that accounted for all areas that would be flooded (i.e., deep and shallow flood waters). The second analysis (A2) followed the same methodology as A1, but each property was classified as at-risk if it would be impacted by IHFAs where flood waters are 30cm (1 foot) or more in depth. Water depth is an important driver of flood damages, as deeper flood waters cause more property damage than shallow waters; therefore, flood water depth is key variable for calculating risk-based premiums (Kundzewicz et al., 2014; National Research Council Canada, 2015).

The third (A3) and fourth (A4) analyses were more lenient than the first two because they used the general vicinity of the address point (i.e., a buffer of 30m) for classifying a property as at-risk of flood. The third analysis used the address points with a 30m buffer and all IFHAs, and the fourth analysis used the address points with a 30m buffer and the IFHAs where flood water depth is 30cm or more. A3 is the most lenient method of the four analyses for detecting property-level flood risk.

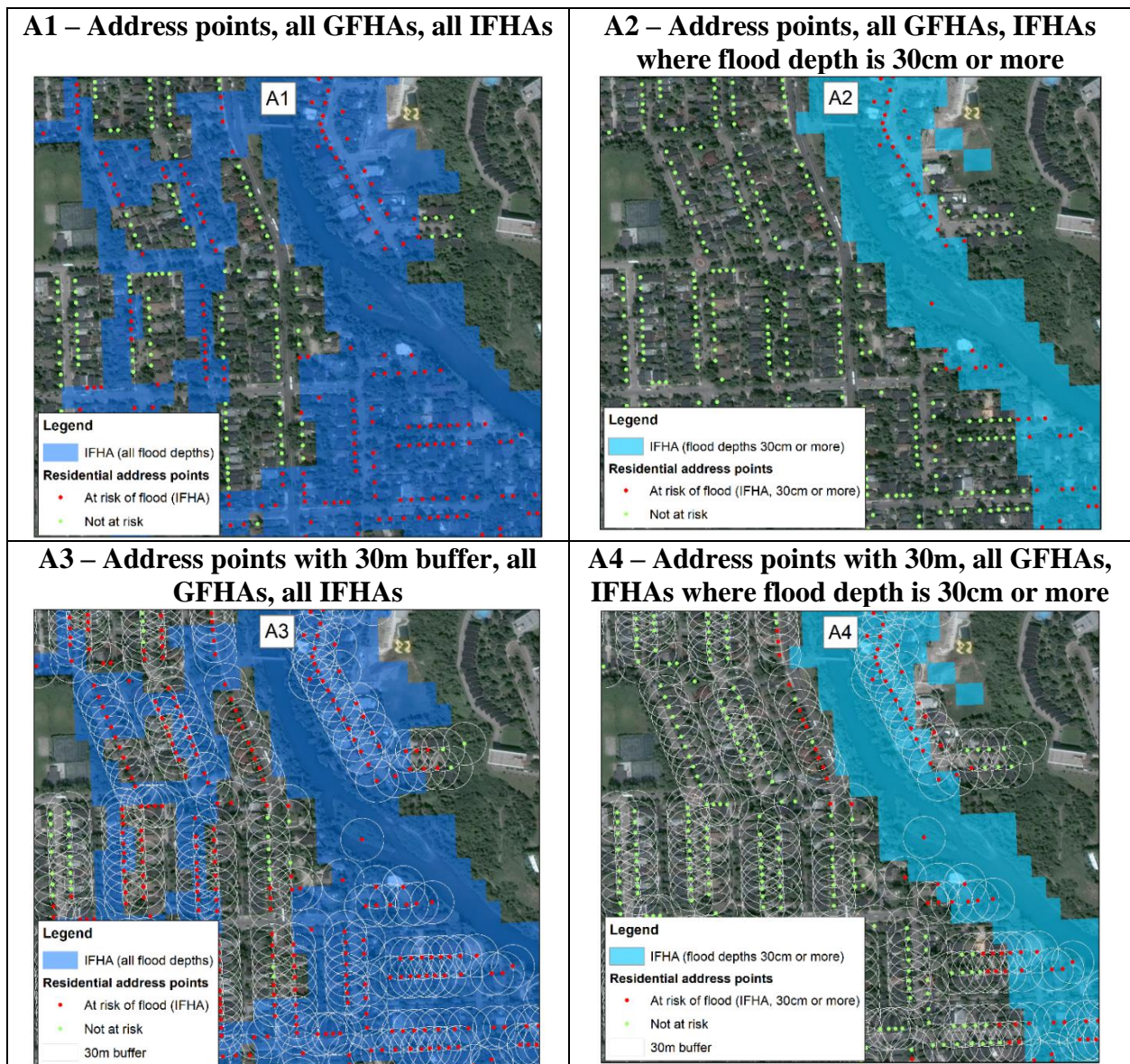


Figure II-3. Differences in methodologies for classifying properties as at-risk of flood

Defended areas

Properties that were in areas protected from floods according to JBA's FDD were also classified. Although it is not known how insurers in practice incorporate flood defences in flood insurance pricing, this additional step provides insight on which at-risk properties may be receiving reduced flood insurance premiums due to the presence of structural flood protections.

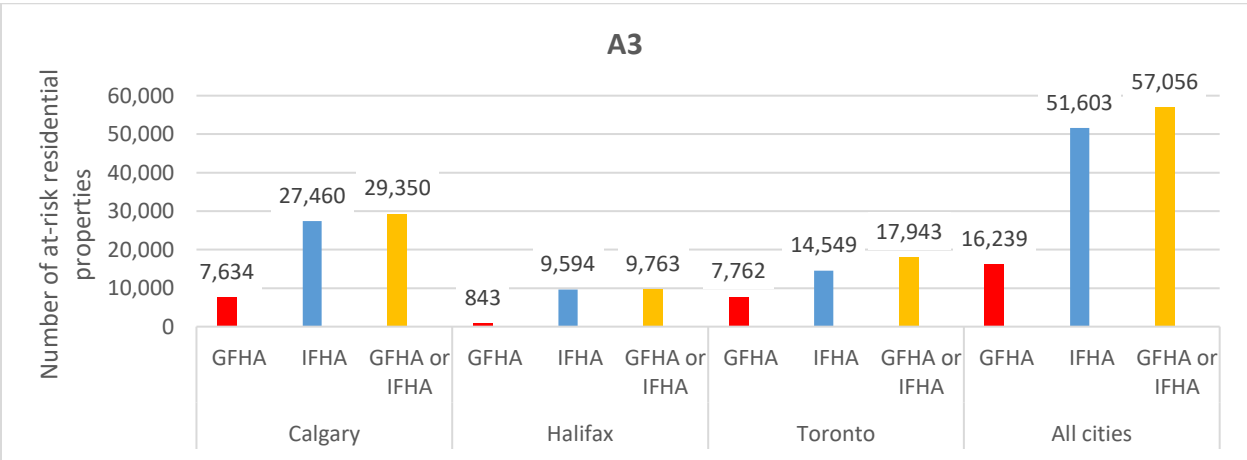
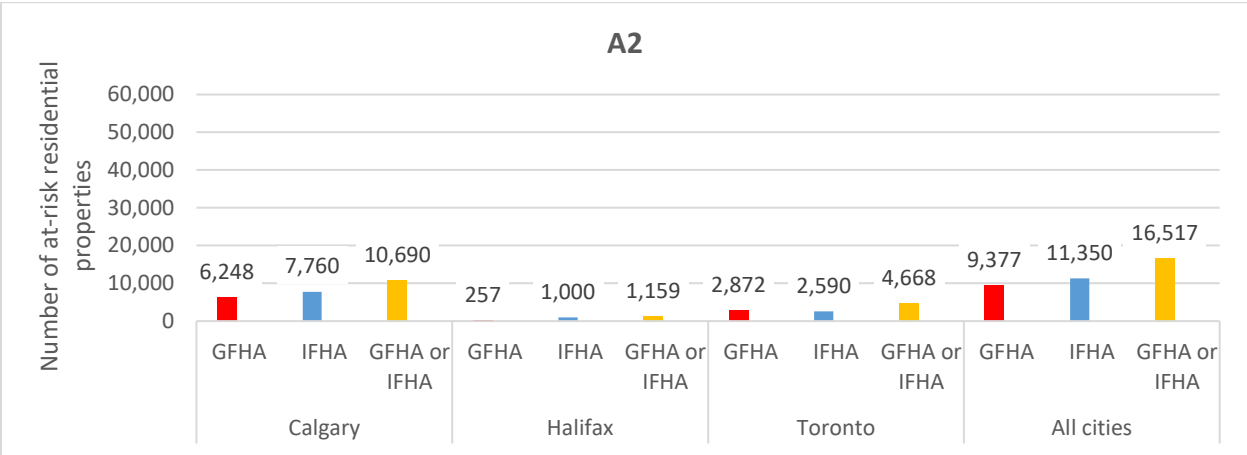
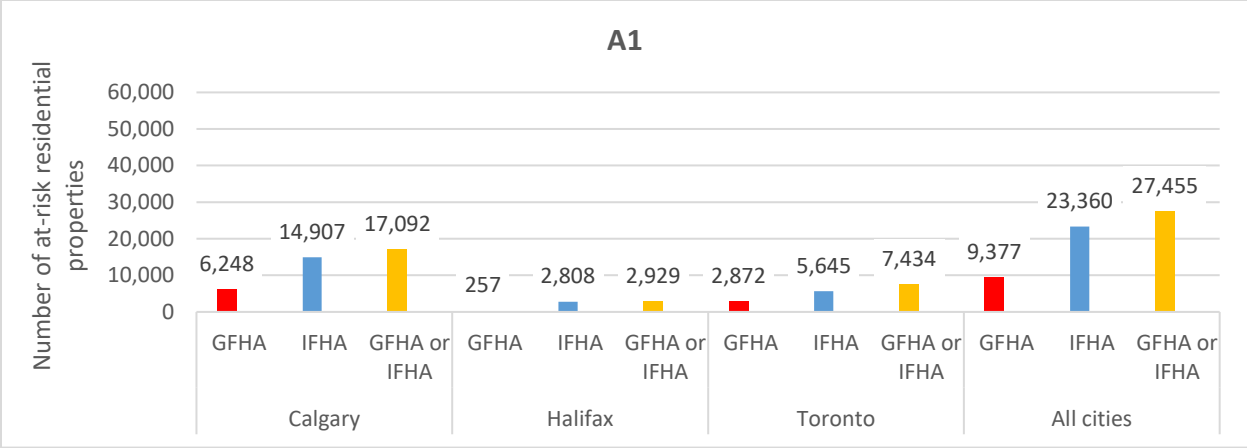
Summary statistics

Finally, summary statistics were computed at the municipal ward level to compare the results between analyses within each city. Municipal wards (or districts in Halifax) are representative of municipal electoral boundaries, so each ward generally has a similar population (City of Calgary, 2021b; City of Toronto, 2021; HRM, 2016).

2.5 Results

2.5.1 Overall results

Across the three cities, 57,056 residential properties were located in GFHAs or IFHAs (6.1% of total)(A3 method). There were particularly few properties in GFHAs in all cities where, even when employing the most lenient method for detecting flood exposure (A3 method), there were 16,239 (1.7%) properties in GFHAs out of all 933,468 single-dwelling residential properties in the three cities (Figure II-4). This is a positive finding that indicates that, to some degree, floodplain regulations have prevented the construction of residential properties on floodplains.



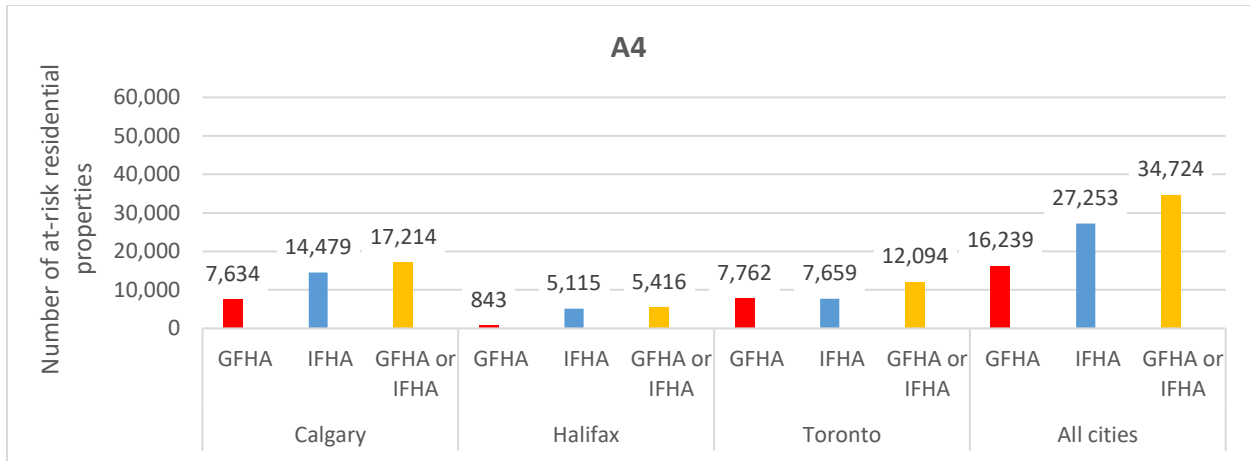


Figure II-4. Results for A1-A4 methods for classifying properties as at-risk of flood. A1 was conducted with the address points, all GFHAs and all IFHAs. A2 was conducted with the address points, all GFHAs and IFHAs where flood water depth was 30cm (1 foot) or more. A3 was conducted with the address points (30m buffer), all GFHAs and all IFHAs. A4 was conducted with the address points (30m buffer), all GFHAs and IFHAs where flood water depth was 30cm (1 foot) or more.

Regardless of the method used for identifying at-risk properties, there were generally more properties in IFHAs than in GFHAs. There were more properties in IFHAs even when reducing the flood extent of IFHAs by excluding shallow flood waters (i.e., less than 30cm in depth)(A2 and A4 methods). Only in Toronto, there were two instances where there were more at-risk properties in the GFHA than the IFHA. There were 282 and 103 more properties in the GFHA than the IFHA using the A2 and A4 methods, respectively. This finding was expected as the regulatory floodplain standard in Toronto exceeds the 100-year flood event. Relative to its single-dwelling housing stock, Toronto consistently had the lowest percentage of properties in GFHAs and IFHAs out of the three cities (3.83% vs. 8.44% in Calgary and 8.30% in Halifax using the A3 method). This could be because Toronto has the strictest floodplain development

rules out of the three cities, which has prevented new residential construction in its entire floodplain, rather than segments within the floodplain like in Calgary and Halifax.

The findings show notable differences in Calgary between the number of properties in GFHAs and IFHAs. Here, 27,460 properties were in the IFHA, while 7,634 were located in the GFHA—a difference of 19,826 properties (A3 method). At the same time, JBA’s FDD indicates that most properties in Calgary are protected against a 100-year flood (Table II-3). Though these properties are situated in the IFHA, they may not be considered high-risk by insurance companies since their risk is mitigated by community-level flood defences.

Table II-3. Number of properties in areas protected from floods. These areas protected from flood impacts were provided by JBA’s FDD.

| Study area | Number of residential addresses (single-dwelling) | Number of properties in areas defended from floods | Standard of protection |
|-------------------|--|---|-------------------------------|
| Calgary | 347,901 | 301,683 | 100-year flood |
| Halifax | 117,657 | 0 | - |
| Toronto | 467,910 | 467,910 | 100-year flood |
| Total | 933,468 | 769,593 | |

This is not the same case for Halifax, where no property is in an area protected from fluvial floods according to the FDD. Halifax also has the fewest properties in government-designated floodplains out of the three cities, yet the IFHA indicated many areas throughout the municipality as being exposed to fluvial floods (Figure II-5). This included developed and undeveloped lands that are currently not designated as floodplains in government documents. This is partly because the municipality’s floodplain regulations have targeted specific

neighbourhoods within the city since the 1980s (e.g., Bedford and Sackville neighbourhoods). For the other two cities, regulatory floodplains are located throughout the whole city.

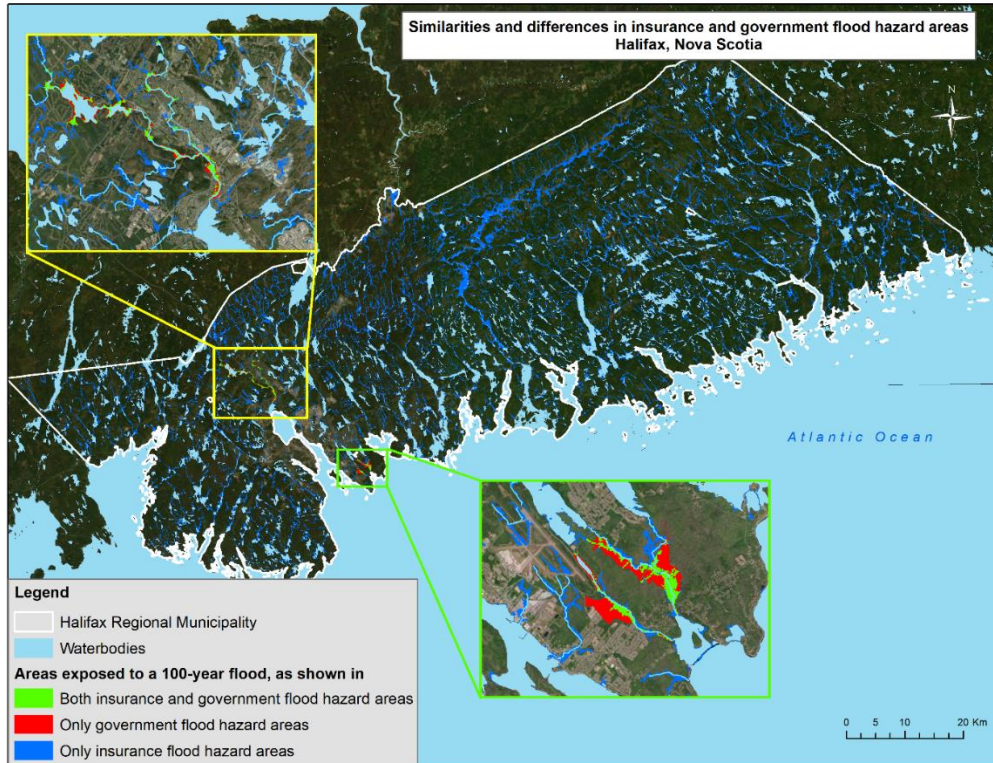


Figure II-5. Similarities and difference in GFHAs and IFHAs in Halifax

2.5.2 Agreement between flood exposure analyses

Overall, there was little agreement between the flood exposure analyses derived using the GFHAs and the IFHAs (Figure II-6). At most, 25.49% of at-risk properties were located in both GFHAs and IFHAs (A2 method). The remainder were either in only the GFHA (31.28%) or only in the IFHA (43.23%). The least amount of agreement was identified using the A3 method where 18.90% of at-risk properties were in both GFHAs and IFHAs, 9.56% were only in GFHAs and 71.54% were only in IFHAs. The disagreement between flood exposure analyses was particularly noticeable in Halifax, where on the upper end only 10.01% of all at-risk properties

were in both the GFHA and IFHA (A4 method). Up to 91.37% of all at-risk properties were only in the IFHA and not the GFHA in Halifax (A3 method).

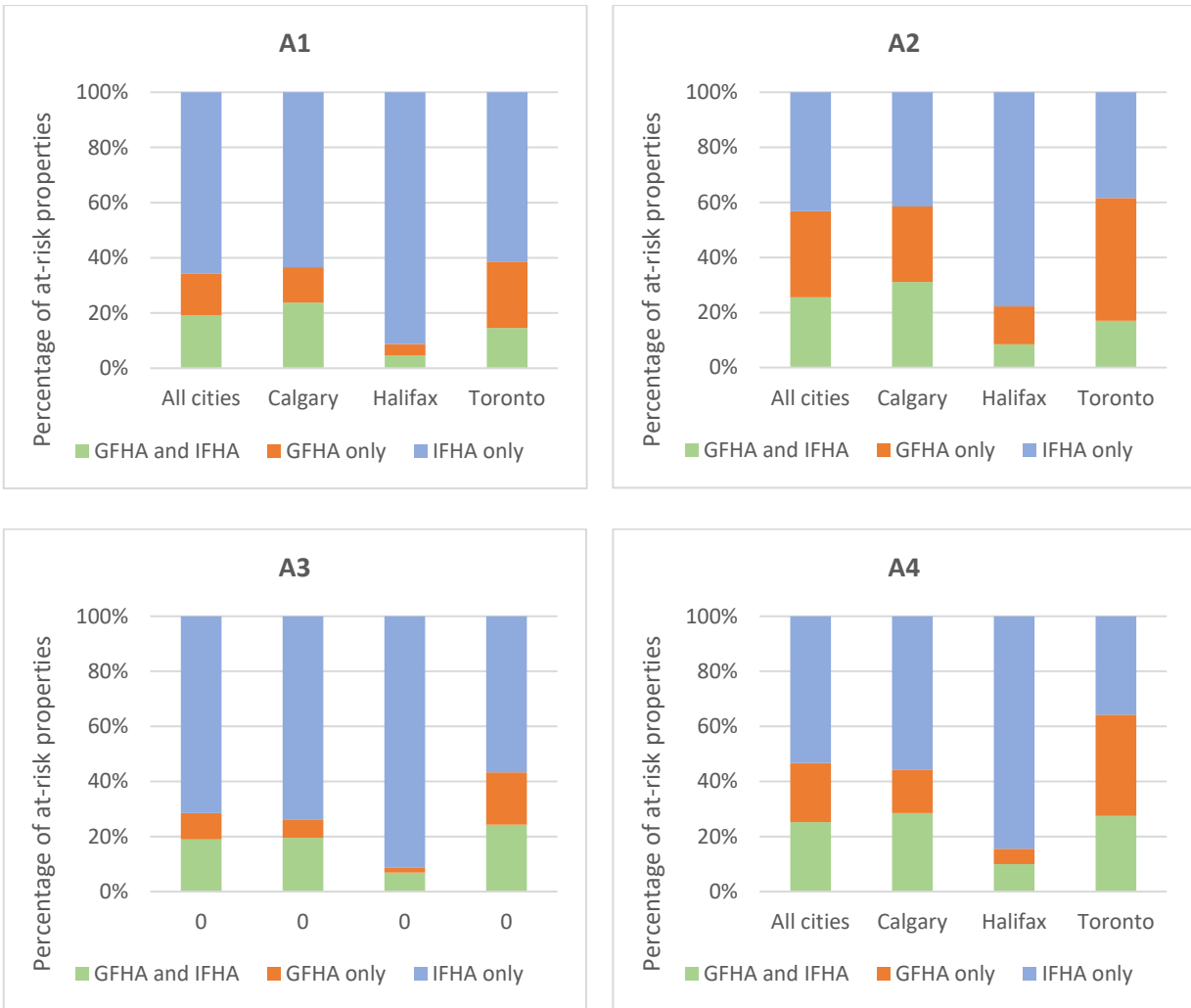


Figure II-6. Agreement and disagreement in residential flood exposure analyses

Within each city, there were also a number of municipal wards where more than 90% of at-risk properties were only in IFHAs and not in GFHAs. That includes 6 out of 14 wards in

Calgary, 12 out of 16 polling districts in Halifax, and 8 out of 25 wards in Toronto (A3 analysis)(Figure II-7).

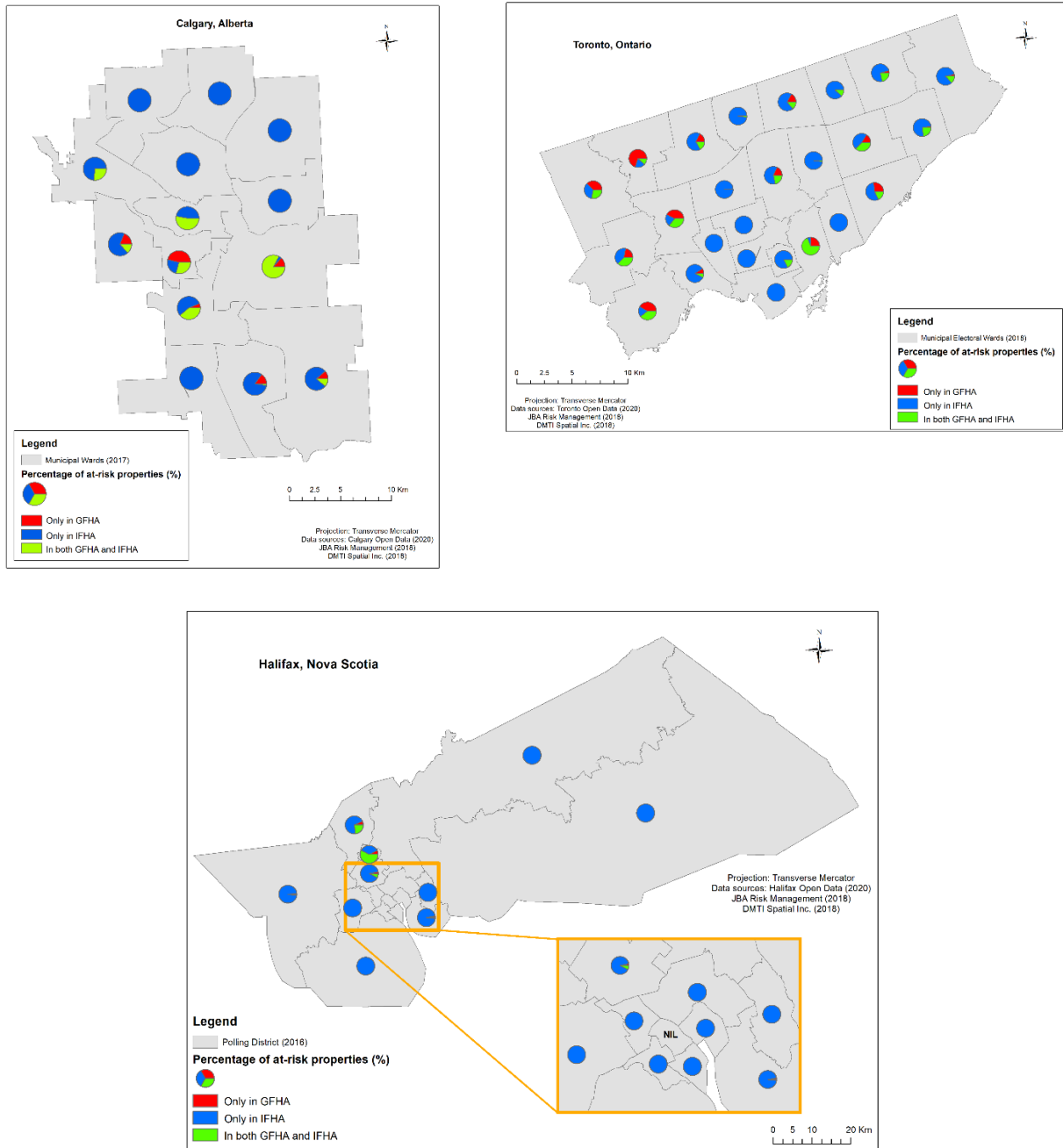


Figure II-7. Percentage of at-risk properties in any flood hazard area, by ward (A3 method)

2.6 Discussion

The overall results show that fluvial flood risk, regardless of whether it is defined by government or insurance flood maps, affects a relatively small percentage of residential properties in the three cities. This is a positive finding which indicates that, to some degree, floodplain development regulations have prevented new residential construction on designated floodplains, particularly in the floodway portion of the floodplain.

There are, however, notable differences in the location and number of flood-exposed residential properties identified using the GFHAs and IFHAs. These differences raise questions for Canada's national flood program that is being designed to target *homeowners at high risk of flooding and without adequate insurance protection*. First, this study's findings show that there are many residential properties in IFHAs that are outside of GFHAs, which raises questions about how many properties there are in Canada that insurers would consider high-risk. This knowledge gap prevents an understanding of how widespread this problem of high-risk populations is in Canada, the reasons why they do not have adequate flood insurance protection, and ultimately how a national flood insurance program can effectively support the current residential flood insurance market and address its limitations.

Second, this study's findings also present opportunities for innovation for managing areas at higher risk of flooding through cross-sectoral collaboration. In particular, there are opportunities for developing a data management system that integrates GFHAs, IFHAs, and other FRM information for overseeing how high-risk and other flood-prone areas are being managed by various sectors across the country. Such a system could create new opportunities for improving FRM, such as for municipalities by accessing other sectors' risk assessments, and also for increasing transparency about how the flood insurance market is operating in different cities

and how it could be supported by governments across all levels (e.g., increasing flood insurance penetration). Integrating data silos could facilitate problem identification, collaborative problem-solving and effective policymaking since problems are explicit and commonly understood by all relevant actors.

The following sections explore these topics in more detail and describe opportunities for innovation and future research.

2.6.1 Where are the homeowners at high risk of flooding and without adequate insurance protection?

This study leveraged government and industry flood hazard datasets to identify residential properties exposed to floods in three cities. The findings offer a first glimpse at how the public and private sectors see the “flood problem” differently and where properties that could experience insurability issues may be located. However, this study does not show conclusively where high-risk properties are to pinpoint residences with inadequate insurance coverage for flood damages. Additionally, it is not known to what extent insurance companies rely on the JBA model when making decisions about where they offer flood insurance cover and when pricing this product. Subsequent analyses could survey populations living in GFHAs and IFHAs to confirm how many of these properties are adequately insured for flood, document any difficulties experienced acquiring flood insurance cover, and assess public interest or disinterest in purchasing this product. The additional data could validate this study’s findings, as well as account for behavioural differences for populations who are aware of their risk because they live in government-designated floodplains, and populations who live in IFHAs that are not accessible for public use.

For the creation of a national flood program that targets high-risk properties, having sound estimates of the number of properties that would be eligible for the program is essential because this can impact the resources required for the program and policies to support key demographics of concern. For example, the program would be inherently different if the majority of high-risk households are either high or low income. On one end, high-income households have a greater ability to pay for higher flood insurance premiums but may choose to purchase limited coverage if the high cost of insuring the whole property is unjustified. To address this scenario, the federal government could consider designing a framework for lowering risk in high-risk areas both at the community- and property- level for incentivizing the market to offer more affordable flood insurance options. On the other end, low-income households could find all available flood insurance options as unaffordable. To address this scenario, the government could consider subsidizing flood insurance premiums for lower income households; however, a separate risk reduction strategy would need to be designed to address moral hazard.

Although some research has sought to identify the socio-economic characteristics of populations at high risk of flood (e.g., Chakraborty, 2019), there is currently no research that (1) provides insights on the behaviours of populations living in GFHAs and IFHAs when seeking and purchasing flood insurance cover, and (2) that confirms that these “high risk areas” are also where flood insurance is unaffordable and unavailable. These additional insights would add much needed local context and validation for informing Canada’s national flood insurance program.

2.6.2 Opportunities for technical and governance innovation

By showcasing what IFHAs look like, it is evident that there are several opportunities for collaboration between insurers (including insurance flood modellers like JBA) and governments. The disagreement between the flood exposure analyses shows that (1) there may be errors in the IFHAs as a consequence of modelling methods and data available to the industry, (2) there may be high-risk areas and/or flood-prone areas that are outside of GFHAs and that governments across all levels should be aware of for FRM, and (3) there are opportunities for integrating data silos through a data management system for supporting and informing cross-sectoral collaboration in FRM.

Being a national flood model, JBA's 2018 Canada Flood Map could have some limitations as a consequence of modelling assumptions or input datasets being used for calibrating and validating the flood model. Similar opportunities as those identified in Germany and Australia may be present in Canada, where local flood experts and municipalities helped enhance the precision of industry flood models. This could be achieved by contributing better input technical data (e.g., Digital Elevation Models), historical flood extents, and data on municipal flood mitigation infrastructure to improve the model's ability to predict where flood waters are likely to cause damage. JBA makes regular enhancements to its model, which presents an opportunity for governments to contribute data that will enhance their ability to predict risk, particularly since these models aim to assess risks at the property-level. This type of collaboration is not limited to JBA as it can also prove useful for other modelling firms driving innovation in flood prediction and forecasting.

Lessons from the international community have shown that government flood maps can underestimate flood exposure (e.g., U.S.)(Wing et al., 2018). This can be because of age, quality

and limited area that was the focus of government floodplain studies (Henstra et al., 2019; Wing et al., 2018). Indeed, in Halifax, for example, governments have focused primarily on fluvial flood risks in specific neighbourhoods (e.g., Bedford and Sackville neighbourhoods), while the IFHAs show fluvial flood hazards in other locations across the municipality as well. At the same time, designating new areas as regulatory floodplains can be highly politically contentious and unpopular among affected residents (Yeo, 2003). Municipalities in Canada have expressed an interest in accessing other sectors' risk assessments to gain a "more complete 'picture' of risk" (CWN, 2020, p. 24), but questions remain about how FRM could be improved in practice if municipalities get access to IFHAs. Without having to update official floodplain lines, for example, governments could support flood insurance uptake in areas where there is disagreement between GFHAs and IFHAs as a precautionary measure. Governments could also incorporate or reference IFHAs for flood risk mitigation planning if deemed adequate for that use, such as leveraging IFHAs that represent flood events that exceed the government's regulatory standards (i.e., 100-year return period). Such options are subject to future debate and consultation with municipalities which can be informed by this study's results.

Finally, there is an opportunity to develop a data management system that is accessible to public and private FRM actors, and that integrates GFHAs, IFHAs and other FRM information for tracking progress in FRM. The development of a data management system with these characteristics could foster a greater understanding of how different sectors are contributing to risk prevention, risk mitigation and financial recovery. For example, indicators that show an annual decrease in the number of high-risk properties due to government risk mitigation investments could incentivize insurers to re-evaluate their flood insurance products in affected areas. If there are tangible benefits, whether it is through greater flood insurance availability or

lower premiums, this can offer an additional incentive for governments to continue to invest in risk reduction as their constituents would benefit directly. A data management system could improve the current capacity to manage changing flood risk, which could incentivize proactive risk mitigation for sustaining the availability and affordability of flood insurance in the long-term.

2.7 Conclusions

International studies have noted the difficulty of accessing insurance flood models, which makes understanding model uncertainties challenging and reduces opportunities to improve FRM by increasing risk information transparency. This study leveraged JBA's 2018 Canada Flood Map to quantify residential flood exposure in three Canadian cities. This model is widely used by the insurance industry to price flood insurance products in Canada. When compared against government-issued floodplain areas, large differences between the number and location of residential properties exposed to floods were observed. This analysis offers a first glimpse at how public and private sectors view the "flood problem" differently, and it provides a foundation for future research on data management and coordinated FRM governance for supporting Canada's efforts to develop a national flood insurance program.

Canada is in a unique position to learn from other countries that have decades of experience with flood insurance, including how governments have intervened to support flood insurance markets. Since flood insurance was introduced in Canada in 2015, there continue to be many knowledge gaps about how the flood insurance market is operating—where flood insurance is available, who has purchased it, and why certain high-risk populations do not have flood insurance cover. Although answering these questions will require further research, this

study provides a foundation for where to target a future in-depth investigation (i.e., properties in IFHAs and GFHAs). Gaining a greater appreciation for the public's experience with flood insurance, particularly those who may be considered high-risk of flood by insurers, can inform the Canadian government's efforts for developing an appropriate solution for high-risk homeowners who do not have adequate flood insurance coverage.

Finally, it is noteworthy to emphasize that bridging public and private silos through an integrated data management system appears to be a promising step for strengthening flood resilience. First, it would enable governments to correct or enhance industry flood models and insurers' ability to assess risk at the property-level, which could ultimately lead to a reduced number of properties deemed as high-risk (as seen in Australia and Germany). Second, increasing transparency about the location of high-risk properties deemed uninsurable could incentivize governments to reduce risk, including in areas outside of designated floodplains, and to hold insurers accountable for re-evaluating risk profiles for protected residences. Third, a data management system accessible to governments and insurers could track progress on FRM with common indicators (e.g., location of exposed properties, risk mitigation projects in place, percentage of at-risk populations with flood insurance) and facilitate problem identification and coordinated responses. Such a system could address persistent gaps in flood resilience literature that demand better interdisciplinary integration for improving the management of flood risk in a time of increasing economic flood damages (Morrison et al., 2018; Ran & Nedovic-Budic, 2016).

Chapter 3

Conceptualizing and evaluating the role of a data platform for strengthening flood risk governance

Minano A., Thistlethwaite J., Henstra D. (submitted). Conceptualizing and evaluating the role of a data platform for strengthening flood risk governance. *International Journal of Disaster Risk Reduction*

Only 18% of global flood losses experienced between 2011 and 2021 have been insured (Bevere & Finucane, 2022). Governments are increasingly examining ways to transfer financial flood risks to the private insurance market. Flood insurance is widely recognized as an effective financial risk-transfer mechanism that helps societies efficiently recover from sudden and unexpected flood losses; however, flood insurance is often unavailable to high-risk properties via the private market. Insurers assert that access to better flood model data and sustained investment in flood damage prevention can foster flood insurance availability and affordability as risks can be more precisely evaluated and fewer damages result from flooding. This paper presents a conceptual framework of a data platform designed to reduce and manage the number of high-risk uninsurable properties through public-private data-sharing. The paper then assesses whether the conceptual data platform has a role to play in Canada by surveying municipalities and insurance companies. The study entailed participation of municipal officials representing 59 Canadian cities, and insurance professionals representing 7 insurance companies. Findings confirm there is appetite for both sectors to engage in cross-sector data-sharing and that the conceptual data platform is perceived as a tool that could establish new forms of collaboration that can lead to changes in flood insurance availability. Other countries experiencing insurance challenges with high-risk properties could benefit from testing the viability of the conceptual data platform in their context.

3.1 Introduction

Flooding is the most common natural hazard, which is estimated to have affected two billion people worldwide between 1998 and 2017 (CRED & UNDRR, 2020; WHO, 2022). Despite many efforts to reduce flood impacts over the years, “losses from flood have been on an upward trend globally and at a significantly faster pace than global GDP” (Bevere & Remondi, 2022, p. 2; Kundzewicz et al., 2014). In 2021 alone, floods caused an estimated US\$82 billion in economic losses making floods one of the most damaging natural hazards worldwide (Bevere & Remondi, 2022; CRED & UNDRR, 2020). It is expected that flood losses will continue rising due to population and asset growth in flood-prone areas (Bouwer, 2013; Kundzewicz et al., 2014). Climate change impacts on sea level and precipitation are also projected to increase the severity of flood impacts in many global regions over the next decades (IPCC, 2022a, 2022b).

The insurance industry can play a more effective role in managing growing flood losses. Recent statistics show that “only 5% of flood losses in emerging markets were insured, and just 34% in advanced economies, pointing to the existence of large flood [insurance] protection gaps across the world” (Bevere & Remondi, 2022, p. 11). In the absence of insured property and assets, governments and citizens are increasingly dealing with the economic consequences caused by flooding (OECD, 2016; PBO, 2016). International bodies, such as the United Nations, recognize the importance of natural hazards insurance and encourage that public and private investments become insured “in order to reduce the financial impact of disasters on Governments and societies” (UNISDR, 2015b, p. 19).

Flood insurance is widely recognized as a mechanism that increases society’s capacity for disaster recovery since it provides financial compensation to individuals in the event of a loss and serves as an avenue for efficient reconstruction (Alexander et al., 2016a; OECD, 2016;

Sayers et al., 2013). However, private flood insurance products are often unavailable for properties considered high-risk of flooding, such as properties on coastal and river floodplains and properties that have flooded in the past (OECD, 2016; Surminski, 2017a). It is therefore unsurprising that flood losses have historically been uninsured because properties most susceptible to flood damages have been excluded from the private market. Encouraging that flood insurance becomes available to higher risk properties is a complex process that has often entailed some arrangement between insurance companies and government agencies (FEMA, 2022; Penning-Rowsell et al., 2014; Surminski & Thielen, 2017).

The global insurance industry has identified various strategies that can promote the widespread availability of flood insurance, including (1) improving industry flood models through access to better data, and (2) addressing the underlying factors that perpetuate flood risk, such as poor land use decisions and insufficient investments in flood protection infrastructure (Bevere & Remondi, 2022; IBC, 2019). There are emerging examples where governments are responding to these industry requests, such as by providing data to insurers for improving the accuracy of industry flood models (Insurance Council of Australia & Floodplain Management Australia, 2019). Pilot initiatives have also allowed municipalities to use insurance claims data for identifying vulnerabilities in municipal flood management infrastructure (Climate-ADAPT, 2021; Prail, 2016). Nevertheless, there continues to be untapped potential in public-private partnerships that effectively promote flood insurance availability to all properties in the short and long-term (Bevere & Remondi, 2022; Minano et al., 2021; Surminski, 2017a).

About 7-9% of residential properties in Canada have been assessed as high-risk by the insurance industry, and the owners of these properties would have difficulty securing flood insurance coverage (Al-Shibeeb, 2022; IBC, 2019). This paper explores the viability of a data

platform designed to manage the flood insurance protection gap in Canada by fostering effective collaboration between municipalities and insurance companies. A data platform is defined as a tool that compiles data from various sources, manages data access and sharing across organizations, and produces analytics and visuals from shared datasets (MongoDB, 2022). Guided by the principles of effective flood risk governance defined by Alexander et al. (2016), a conceptual data platform is proposed to establish a shared view of the flood insurance market among public and private actors, increase visibility of government investments in data collection and flood protection infrastructure, and facilitate continuous collaboration towards shared goals. The study sought input from municipalities and insurance companies using two survey instruments to assess stakeholders' appetite to use the proposed data platform, gauge their overall willingness to collaborate and share resources, and identify the benefits this tool could generate if it were to be implemented in practice, such as changes to flood insurance availability among high-risk properties.

3.2 Governance for flood resilience

Analysts argue that current approaches to flood risk management (FRM) are insufficient to cope with increasing flood losses and future climate uncertainty (Hegger, Driessen, Wiering, et al., 2016). Over the last two decades, the concept of “governance for resilience” has gained the interest of many scholars who are analyzing the “actor networks, rules, resources, discourses and multi-level coordination mechanisms through which FRM is pursued” to identify entry-points for improvement (Alexander et al., 2016, p. 39; Morrison et al., 2018). Governance studies have gained momentum in FRM literature because of the notion that effective FRM is achieved through the concerted, integrated and well-coordinated actions of traditional government institutions and non-government actors, such as citizens, property developers, banks, insurance

companies, and others (Alexander et al., 2016a; Hegger, Driessen, Wiering, et al., 2016; Morrison et al., 2018; Sayers et al., 2013). Effective flood risk governance ultimately increases flood resilience by strengthening society's capacity to resist, recover from and adapt to flood impacts (Alexander et al., 2016). However, encouraging participation and ensuring that actions taken by public and private actors symbiotically increase flood resilience can be a complex process, requiring deliberate interventions that "support integration and coordination between different levels of governance" (Alexander et al., 2016a, p. 40; Gilissen et al., 2015).

Despite the recognition that effective flood risk governance involves multi-sectoral collaboration, there are few studies on the development and use of frameworks and tools that "foster collaboration, share knowledge, determine roles and responsibilities, and provide an arena for continuous learning and policy development and evolution" (Morrison et al., 2018, p. 300). The authors add that "to advance FRM tool development...[what is] needed is greater collaboration across the FRM research community, as well as enhanced collaboration with practitioners" to ensure the tools developed "are integrative and flexible to local or regional governance contexts" (Morrison et al., 2018, p. 300). This study aimed to address this gap by developing a conceptual model of a tool that could strengthen flood risk governance and validating this concept with feedback from FRM practitioners.

3.2.1 The role of insurance in flood risk governance

Insurance companies are an interesting group of actors to analyze in the context of integrated flood risk governance because they are private actors who can assist governments and civil society in building flood resilience. Insurers are widely recognized as contributors to society's *capacity to recover from floods* since they provide financial resources to policyholders to restore

flood-damaged properties quickly and efficiently (OECD, 2016). Insurers can also increase society's *capacity to resist and adapt to floods*, such as by encouraging property owners to proactively floodproof their properties by offering premium discounts (e.g., Botzen et al., 2010). Yet, despite the potential for the insurance industry to play an important role in flood risk governance, the lack of insured flood losses worldwide and limited evidence of insurers' influence in flood risk reduction shows there is much to be desired from current flood insurance markets (Surminski & Thielen, 2017; Swiss Re, 2019).

Experience shows that the measures needed to close the flood insurance protection gap are not taken by insurance companies alone. One of the common limitations with private flood insurance markets is the limited availability and affordability of flood insurance coverage for high-risk properties (FEMA, 2022; PSC, 2020; Sandink, 2013). These high-risk or “uninsurable” properties are those most likely to experience flood damages because they are near waterbodies (e.g., within 100m from rivers and oceans), have a history of flooding, or have been identified as exposed to frequent flooding by a flood model (Surminski, 2017a). Insurers argue that two main preconditions could expand flood insurability, including: (1) improving insurers' flood models through access to better data, and (2) preventing and mitigating physical flood risks through floodplain regulations and flood protection investments (Bevere & Remondi, 2022; Floodplain Management Australia, 2015; IBC, 2019). Achieving these preconditions inevitably requires a collaborative arrangement between insurers and governments, since the latter has access to salient data and exercises authority over infrastructure and land use decisions (FEMA, 2022; Floodplain Management Australia, 2015).

3.2.2 Data-sharing partnerships

Data-sharing partnerships are arrangements in which a set of actors agree to share their data in the pursuit of a mutual interest. Data-sharing partnerships can entail legal agreements that establish rules for using shared datasets and can also require supporting technologies (e.g., Web interfaces) that allow users to download and analyze shared datasets (Wernick & Olk, 2020). In flood risk governance literature, data-sharing partnerships are referred to as “transfer mechanisms” that enable “inter-organizational communication and other information-sharing or exchange structures, such as shared databases or maps” (Gilissen et al., 2015, p. 16).

There are now some documented examples where government agencies and insurance companies have partnered in data-sharing to improve the accuracy of insurers’ flood models and property flood risk evaluations. For example, the Insurance Council of Australia established the Property Resilience and Exposure Program (PREP) to aggregate data on flood hazards and the built environment collected by local governments in Australia in order to generate a National Flood Information Database for insurers to use in underwriting flood risk (Floodplain Management Australia, 2015). Similarly, German water authorities contributed land elevation data and local flood hazard data to the insurance industry’s national flood hazard zoning system (ZÜRS) upon realizing that ZÜRS’ contained “[flood] maps [that] were based on a coarse [digital elevation model] and a rough hydraulic modeling approach and did not consider structural flood protection such as dikes” (Surminski & Thieken, 2017, p. 989). Once government data became accessible, insurers re-evaluated property-level flood risk profiles, reportedly leading to a reduction in the number of parcels deemed “high-risk” and subsequent lower flood premiums for those redesignated as lower risk. These two examples demonstrate that

data-sharing partnerships can promote flood insurance availability and affordability by improving the accuracy and confidence in insurers' flood models.

In addition to facilitating the transfer of government data to insurance companies, data-sharing partnerships can also facilitate the reverse information flow. In both Norway and Canada, for instance, insurers transferred their flood insurance claims data to local governments to enable them to identify areas where FRM infrastructure should be upgraded (Climate-ADAPT, 2021; Praill, 2016). Though innovative in their approach, these types of data-sharing partnerships are nascent often not advancing beyond their pilot launch, while their influence on government decision-making also remains unclear.

Current evidence shows that data-sharing partnerships can alleviate insurability issues in high-risk areas by helping insurers better evaluate property flood risks. However, there is a considerable research opportunity to explore other applications of data-sharing partnerships for building resilience that could also be conducive to closing the flood insurance protection gap. For example, evaluating the use of industry flood maps in land use planning to prevent the construction of more high-risk uninsurable properties. At the same time, research on public-private data-sharing is likely to come with roadblocks given documented concerns with data-sharing, such as data confidentiality, commercial sensitivities, and data privacy restrictions (O'Hare et al., 2016).

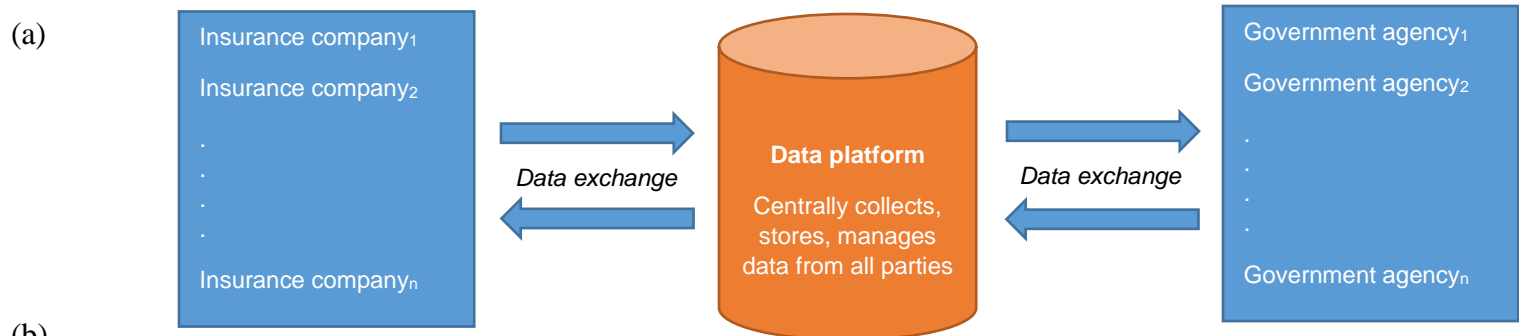
3.3 A data platform for strengthening flood resilience

As mentioned, recent reviews revealed that flood risk governance literature lacks research on frameworks and tools that facilitate knowledge-sharing, organize institutions and available resources, and foster cross-sector collaboration in ways that strengthen flood resilience

(Morrison et al., 2018). Reviews have also found a lack of research that integrates different disciplines pertaining to FRM, such as social, scientific, and technical (McClymont et al., 2019; Morrison et al., 2018). These literature gaps present an opportunity to explore the role that government-insurer data-sharing tools could have in building flood resilience and how these tools could be designed to fulfill this objective.

Data platforms are tools that integrate data from various sources, facilitate data-sharing across organizations, and derive novel insights from shared datasets (MongoDB, 2022). In the context of flood resilience, a data platform could be used to aggregate data produced by multiple government agencies in a central repository and facilitate its transfer to insurance companies (e.g., such as in Australia's PREP program). However, data platforms can store other types of data and facilitate other types of data-exchange, such as by enabling the dynamic exchange of data between governments and insurers and vice versa.

A data platform is conceptualized here as a tool that assists governments and insurers improve flood insurance availability and affordability, increase uptake of flood insurance, and maintain an acceptable level of physical flood risk through data-exchange (Figure III-1). Inspired by past data-sharing partnerships (e.g., Australia and Germany), the data platform presented aims to facilitate the transfer of government data to insurers to improve the accuracy and confidence of industry flood models. However, this conceptual data platform expands on these capabilities by drawing guidance from Alexander et al. (2016)'s flood risk governance evaluation framework. Alexander et al.'s framework is particularly useful for conceptualizing the data platform because this framework helps identify the types of cross-sectoral interactions the data platform could facilitate for strengthening flood resilience in a legitimate and resource-efficient manner.



(b)

| Core features of data platform | Technical role of data platform | Processes targeted by the data platform | Intended outcomes facilitated by the data platform |
|---|--|---|--|
| (1) Provide government officials a platform to share their flood data with insurers (e.g., LiDAR data, flood protections, flood proofed properties) | Collects, stores, and manages government data in a central data repository | <ul style="list-style-type: none"> Flood modelling and property risk evaluation processes used for insurance purposes Flood insurance underwriting and risk pricing | <ul style="list-style-type: none"> Increases visibility of available data resources and promotes re-use of available government data among insurance companies (<i>legitimacy, resource efficiency</i>) Improves accuracy of insurers' property flood risk assessments, potentially leading to fewer properties considered high-risk and uninsurable, lower premiums (<i>capacity to recover</i>) |
| (2) Provide government officials a platform to use insurance flood data (e.g., industry flood maps, high-risk areas identified by insurers, water damage claims, industry flood maps that capture climate change scenarios) | Collects, stores, and manages insurance data in a central data repository | <ul style="list-style-type: none"> Land use planning and floodplain regulations Flood protection infrastructure plans, such as for new construction projects or for upgrading existing infrastructure | <ul style="list-style-type: none"> Increases understanding of properties and areas the whole insurance industry tends to classify as high-risk and uninsurable (<i>legitimacy</i>) Creates opportunities for governments to challenge insurers' flood risk analyses if these are perceived/found to be inaccurate (<i>legitimacy</i>) Creates opportunities for governments to reflect insurers' FRM data and insights in land use and flood infrastructure, and potentially identify flood-prone areas that were previously unaccounted for (<i>capacity to resist, capacity to adapt</i>) |
| (3) Provide a platform for governments to share updates in FRM with insurers | Collects and aggregates updates from governments to provide a national view of updates to insurers | <ul style="list-style-type: none"> Insurance policy renewal processes (e.g., annual policy renewals) | <ul style="list-style-type: none"> Increases visibility among insurers of recent FRM actions taken by governments, such as new flood protection infrastructure, new flood data produced over the last year (<i>resource efficiency</i>) Encourages insurers to reflect recent changes in FRM in insurance policy renewal cycles (e.g., new flood protection infrastructure), potentially reducing premiums for areas recently protected from flood impacts (<i>capacity to recover</i>) |

| | | | |
|---|--|--|--|
| | | | <ul style="list-style-type: none"> Encourages governments to continuously prioritize preventative FRM, particularly if their investments lead to changes in flood insurability (<i>capacity to resist</i>) |
| (4) Provide a platform for insurers to suggest changes and improvements in FRM to governments | Collects and aggregates suggestions from insurance companies to provide a national, state, or local view of suggested FRM improvements | <ul style="list-style-type: none"> Local and upper-level government FRM plans, programs, projects, and policies | <ul style="list-style-type: none"> Allows insurance companies to provide suggestions on what measures could be taken to alleviate flood insurability issues further (<i>resource efficiency</i>) Encourages governments to make periodic modifications to FRM plans, programs, and policies given insurers' suggestions on which FRM measures could further promote flood insurability (<i>capacity to adapt</i>) |
| (5) Provide a platform where government officials can track progress in FRM using a set of common indicators (e.g., properties insured for flooding, high-risk properties) | Given that government and insurance data is centrally stored, the data platform can compute "resilience" indicators for tracking progress in FRM, and comparing progress between jurisdictions | <ul style="list-style-type: none"> Local and upper-level government FRM plans, programs, projects, and policies | <ul style="list-style-type: none"> Increases visibility among government officials about the regions and communities experiencing the highest rate of high-risk uninsurable properties, lowest rates of insured households for flooding (<i>legitimacy</i>) Increases visibility of jurisdictions that are permeating flood risk, such as by continuing to allow construction on floodplains (<i>legitimacy</i>) Allows government officials across all levels to monitor changes in FRM and the flood insurance market and allocate resources more effectively (<i>resource efficiency, capacity to adapt</i>) |
| (6) Provide insurers a platform to view industry-wide statistics on the flood insurance market (e.g., number of properties insured for flood, number of high-risk uninsurable properties) | Given that insurance data is centrally stored, the data platform can provide industry-wide insights on the evolving nature of the flood insurance market | <ul style="list-style-type: none"> Insurers and industry associations' policy positions and discussion papers | <ul style="list-style-type: none"> Establishes a consistent understanding of flood insurability issues among insurance companies (e.g., number of high-risk uninsurable properties) (<i>legitimacy</i>) Promotes policy position papers, discussions and debates are based on the same understanding of the flood insurance market and its limitations (<i>legitimacy</i>) |

Figure III-1. A framework of a data platform for strengthening flood resilience through governance integration. Where (a) visualizes the flow of data between many insurance companies and many government agencies facilitated by the data platform. And (b) outlines the main features of the data platform and how these features are designed to strengthen the ability for flood risk governance to increase flood resilience (i.e., capacity to resist, recover and adapt to flooding), legitimacy, and resource efficiency.

Guided by Alexander et al.'s framework, the data platform is designed to foster cross-sector interactions that enhance flood resilience in three ways. First, to enhance *capacity to resist flooding*, the data platform provides government agencies' access to industry flood maps and claims data that can inform flood infrastructure plans and land use decisions. Second, to increase *capacity to recover from flooding*, the data platform increases visibility of flood infrastructure projects among insurers to encourage this information leads to immediate changes in flood insurance availability and pricing. Third, to increase *capacity to adapt to flooding*, the data platform allows governments to monitor changes in the flood insurance market, access alternative flood maps and adjust FRM plans on an ongoing basis considering new information. Finally, the data platform is also designed to enhance *legitimacy* in decision-making through information transparency and *resource efficiency* by encouraging the re-use and re-purposing of available data resources in the public and private sectors.

In summary, the data platform conceptualized here could assist in reducing the number of high-risk uninsurable properties while also maintaining an acceptable level of physical flood risk that could promote that flood insurance remains available and affordable in the long-term.

3.4 Evaluating the viability of a data platform in Canada

3.4.1 Study objectives

The proposed data platform is administratively and technically complex to implement. It requires that public and private actors recognize the utility of the data platform for FRM, be willing to partner with each other in data-sharing and contribute time and resources to this initiative. As such, the objective of this study is to evaluate whether the conceptual data platform has a role to

play and is a viable tool for strengthening flood risk governance in Canada. There are four reasons why Canada is a suitable case study for this analysis:

- (1) **Floods are causing increasing economic damages, which are expected to worsen in the future.** Recent flood events have caused some of the greatest economic impacts due to natural disasters in Canadian history (Haney, 2017; PBO, 2016). In reaction to this trend, federal funding programs have been launched to improve flood risk identification and flood damage prevention (P. S. Canada, 2018). However, there continue to be calls to further strengthen flood resilience in Canada (FCM, 2022).
- (2) **Canadian flood risk governance is fragmented.** Canada is a federal state where responsibilities for fluvial, pluvial, and coastal FRM are fragmented across the federal, provincial and municipal levels of government and no single agency oversees FRM holistically. Data on flood hazards and the built environment (e.g., FRM infrastructure, building footprints) is scattered across numerous government data repositories that exhibit varying degrees of completeness and quality (Henstra et al., 2019). The insurance industry has its own sets of national flood maps sourced from third-party modelling agencies; and these flood maps differ from regulatory and publicly-accessible flood maps (Minano et al., 2021).
- (3) **The private flood insurance market has limitations.** Insurers began offering residential overland flood insurance in 2015, but it remains unavailable to a broad swath of high-risk properties. Industry estimates indicate that 7-9% of the housing stock—up to 1 million properties—is at high-risk of flooding (IBC, 2019). This proportion of high-risk properties has remained virtually unchanged since 2015, and, in 2022, an industry spokesperson stated that both flood insurance premiums and the number of high-risk

properties are expected to increase given that “Canada is becoming a riskier place to insure” and because “municipalities across Canada continue to allow development in floodplains” (Al-Shibeeb, 2022; Calamai & Minano, 2017). A national task force was established in 2020 specifically to identify options to “protect homeowners who are at high risk of flooding and don’t have adequate insurance protection” (P. S. Canada, 2020).

(4) **Past attempts to establish government-insurer data-sharing.** In 2014, the Insurance Bureau of Canada (IBC), a national industry association representing property insurers, launched the Municipal Risk Assessment Tool (MRAT)—a spatial data management system that allowed municipal engineers find vulnerabilities in municipal FRM infrastructure by analyzing insurance claims data among other climate change forecasting data (Prail, 2016). Though commended for its novelty, MRAT ceased to exist following its pilot launch. A 2020 report supported by IBC re-ignited the idea of a cross-sector data-sharing partnership by proposing the establishment of a Centre designed to increase municipal capacity to mitigate risks from flooding and climate change by providing municipalities access to other sectors’ data and decision support tools (CWN, 2020).

Analyzing the conceptual data platform is timely because Canadian governments and insurers are seeking solutions for high-risk uninsurable properties and recent discussions have included the idea of a cross-sectoral data-sharing for improving FRM.

3.4.2 Study methods

To assess the viability of a data platform in Canada, two survey instruments were created to poll government officials and insurance professionals on: (1) their interest in accessing data from the

other sector, (2) their willingness to contribute data to the platform, and (3) perceived strengths and weaknesses of the data platform and its role in FRM.

For this initial round of consultations, this study specifically focused on the perspectives of property insurance companies with operations in Canada and local (i.e., municipal) government officials. Gauging municipal views on the data platform is important because local governments are often custodians of detailed data about their communities that could be of benefit to insurers (FMA, 2022; Henstra et al., 2019). Municipalities are also responsible for important aspects of FRM, such as river and coastal floodplain delineation and mapping, floodplain development regulations, stormwater management, and property-level flood-proofing policies and programs. They also manage river and coastal flood protection infrastructure which prevent and reduce physical flood risks in high-risk areas. Municipalities could benefit from a data platform, particularly if this tool helps them access new information and resources for advancing local flood resilience efforts.

The next three sections describe the study methods, including participant selection, survey design, and survey administration.

Participant selection

Municipal officials

Canada has over 5,000 municipalities but most of its population resides in urban centers (Government of Canada, 2017, 2022c). In addition to being population and infrastructure hubs, cities have also experienced severe flooding in recent years and they are exposed to flood hazards caused by river overflow, heavy rainfall, storm surges, and ice jams (PBO, 2016;

Sandink, 2013). Therefore, this study targeted municipalities classified as incorporated cities², which included all cities across nine provinces totaling to 166 municipalities (Figure III-2). According to the 2021 census, these 166 cities are home to 19.7 million people, representing more than half of Canada’s population of 36 million (53%) and nearly 70% of the population in the nine provinces ; Government of Canada, 2022b). Appendix A lists the 166 cities whose participation was requested for the study. Quebec was the only province not targeted for this study due to the researchers’ limitations in translating the survey to French.

² Municipalities categorized as “cities” by Statistics Canada (Government of Canada, 2019). For the Province of Nova Scotia which does not have “cities”, “regional municipalities” were selected instead since these are the closest equivalent.

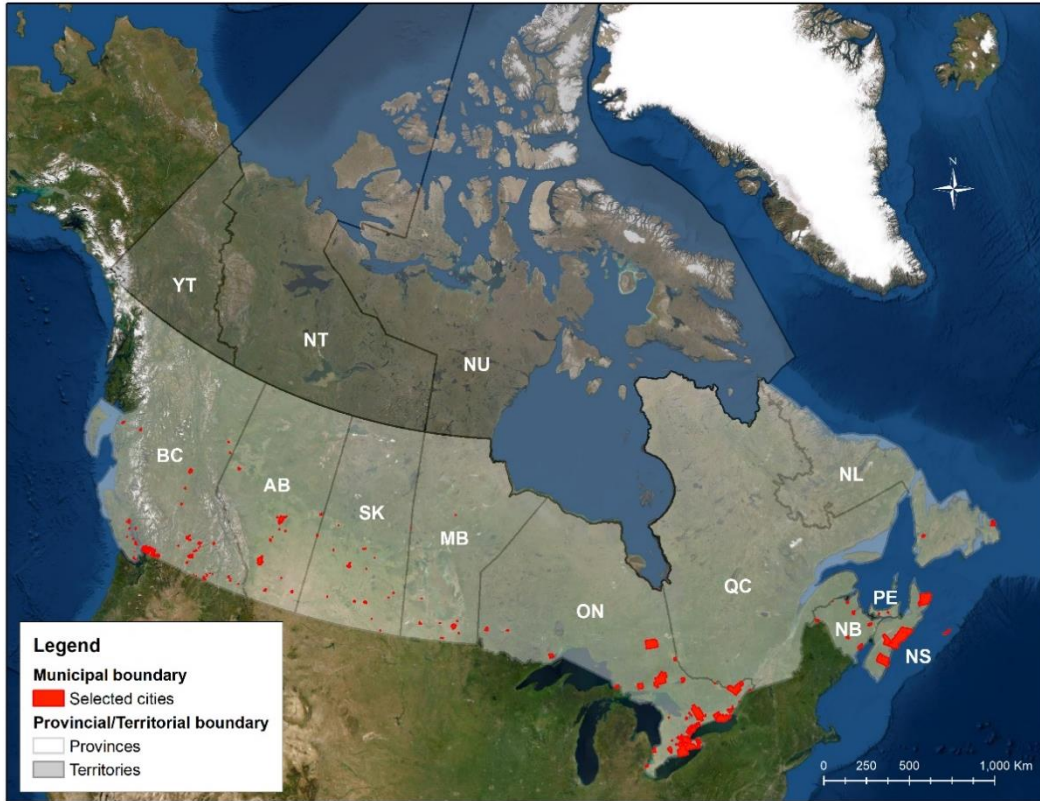


Figure III-2. Map of selected cities. Map contains information licensed under the Open Government License – Canada (Government of Canada, 2022d). Basemap sources: Esri and partners.

With the list of 166 cities, it was then possible to identify municipal government representatives for each city. Municipal directors and managers with duties in engineering, public works, and planning departments were targeted for the survey, on the logic that they would be most familiar with their city’s efforts in various aspects related to FRM (e.g., stormwater management, infrastructure maintenance). It was also assumed that these municipal officials and/or staff they supervise could be users of a data platform if it were to be implemented. Email addresses for municipal staff were gathered from public government websites, and this contact information was found for nearly all directors and managers in the

departments of interest. If the contact information was unavailable for an employee in these departments, the email address of the city manager or Chief Administrative Officer was recorded instead.

Insurance industry representatives

Insurance industry representatives were recruited through existing professional networks of the researchers and through a presentation at a meeting organized by IBC of insurance professionals in December 2021. Via these two approaches, the contact information for insurance industry representatives of 12 companies were collected. Senior staff in insurance companies were targeted, such as managers, directors, and vice presidents, who have knowledge of flood insurance products and how these products are developed by their company (i.e., data used for pricing flood risk). The sample was deemed sufficient since only 16 insurance companies offer residential flood insurance products in Canada (IBC, 2019).

Survey design

Two surveys were created, one for municipal officials and the other for insurance representatives (Appendix B). Each survey comprised 22 questions, most being multiple-choice. The survey instrument for municipal officials contained six open-ended questions and the survey to insurance representatives contained five open-ended questions. Many of the multiple-choice questions employed a Likert scale to capture respondent preferences (e.g., from very desirable to very undesirable).

Despite targeting different stakeholder groups, the core objective of both surveys was the same: to assess the viability of a data platform for strengthening flood risk governance in Canada. To this end, the survey questions were designed to gather stakeholder perspectives on:

(1) their interest in and willingness to participate in FRM data exchange, and (2) their views on the conceptual data platform, its features, and its potential role in FRM.

To ensure participants understood the concept, both surveys described the data platform as a “a platform designed to manage and visualize flood risk data owned by a range of public and private organizations”. Participants were also informed about the features of the proposed data platform (Figure III-1) and were asked to rate the desirability of these features. For example, the survey to insurers used a 5-point Likert scale to ask if it was “desirable” for the data platform to allow their company to “share information with governments about areas and properties at high-risk of flood”. Similarly, the other survey used the same 5-point Likert scale to ask municipal officials if it was “desirable” for the data platform to show them the “location of high-risk areas that insurance companies have identified”.

With this background, municipal and insurance industry respondents were asked to reflect on the conceptual data platform and the role they perceive it playing in FRM. Low willingness to participate in data-sharing and a lack of interest in the conceptual data platform would demonstrate that the data platform is not a viable solution for Canada.

Survey administration

Both surveys were administered using Qualtrics, a cloud-based software to deploy surveys electronically and securely. Qualtrics was used to invite participants by email to complete the survey, create a personalized survey link for each participant, collect survey responses, track completed surveys, and send reminder emails.

The municipal survey was administered first, with email invitations sent between July 6, 2021 to September 30, 2021. This email included a personalized link to complete the survey as

well as materials describing the background of the study and the study consent form. Participants were encouraged to work with other city staff to complete the survey because responsibilities for FRM are often distributed among several staff in municipalities (e.g., planning department administers land regulations on floodplains while public works focuses on stormwater management). Participants were also encouraged to contact the researcher if they were not the most suitable representative to answer the survey questions, whereupon they could recommend a better contact.

Following the survey data collection from municipal officials, the second survey was administered to insurance representatives via email. This email included background information on the study, the study consent form, and a personalized link to complete the survey. Insurance representatives were also encouraged to collaborate with other employees if they were unsure of their answers or to suggest a better suited representative of their company to participate in this study. The data collection period for the second survey occurred between December 15, 2021 and February 8, 2022.

3.5 Results

3.5.1 Survey respondents

By the end of the survey data collection period, government representatives from 59 of the 166 cities targeted for this study had completed the survey (35% response rate) (Table III-1). There was at least one survey response for each of the nine provinces.

Table III-1. Number of cities that completed the survey

| Province | Number of cities targeted for this study | Number of cities that completed the survey |
|---------------------------|---|---|
| Alberta | 19 | 6 |
| British Columbia | 53 | 19 |
| Manitoba | 10 | 3 |
| New Brunswick | 8 | 3 |
| Newfoundland and Labrador | 3 | 2 |
| Ontario | 52 | 18 |
| Prince Edward Island | 2 | 1 |
| Saskatchewan | 15 (+ 2 cities shared with Alberta and Manitoba)* | 5 |
| Nova Scotia | 4 | 2 |
| Total | 166 | 59 |

*City of Flin Flon shares territory with Manitoba and Saskatchewan; City of Lloydminster shares territory with Alberta and Saskatchewan.

Approximately 11.3 million people live in these 59 cities, representing 30% of Canada’s national population and 40% of the population in the nine provinces. The participating cities varied in population size: whereas 22 were large cities (i.e., 100,000 or more people), 17 were mid-sized cities (i.e., between 30,000 to 99,999 people), and 20 were small cities (i.e., between 1,000 to 29,999 people).

Municipal officials who completed the survey varied in their professional training and duties. Most government respondents (40/59; 68%) had professional duties related to public works, engineering, and/or utilities. The remaining 19 had varying duties related to FRM, including municipal planning and growth management, climate change and sustainability, municipal risk management and insurance, and public safety and emergency services.

Out of the 12 insurance companies targeted for this study, representatives from seven completed the survey (58% response rate). Insurance survey respondents generally held senior positions (e.g., managers, directors) and specialized in relevant fields (e.g., actuarial science,

personal insurance, hazards modelling). All insurance companies involved in this study confirmed they sell residential flood insurance products in Canada.

3.5.2 Survey responses

The survey responses demonstrated a mutual interest to participate in cross-sector data-sharing for improving FRM. Representatives of both sectors generally supported the development of the data platform but also highlighted potential implementation issues that urge careful reflection. The following three sections describe these findings in detail.

Interest in data-sharing

Result #1: Insurers are willing to share data that could improve municipal capacity to manage flood risks

The survey results confirmed that only 6 municipal officials (6/59; 10%) have access to flood insurance data or information, such as industry flood hazard maps, and neighborhoods and postal codes that the insurance industry considers high-risk. This result confirms that it is rare for Canadian municipal officials to have access to any flood insurance data or information.

Although flood insurance information is largely unavailable to municipalities, most municipal officials believed that flood insurance information could improve their municipality's FRM efforts (Figure III-3). Of 59 municipal officials, 50 (85%) believed flood insurance information would "probably" or "definitely" improve their municipality's FRM efforts.

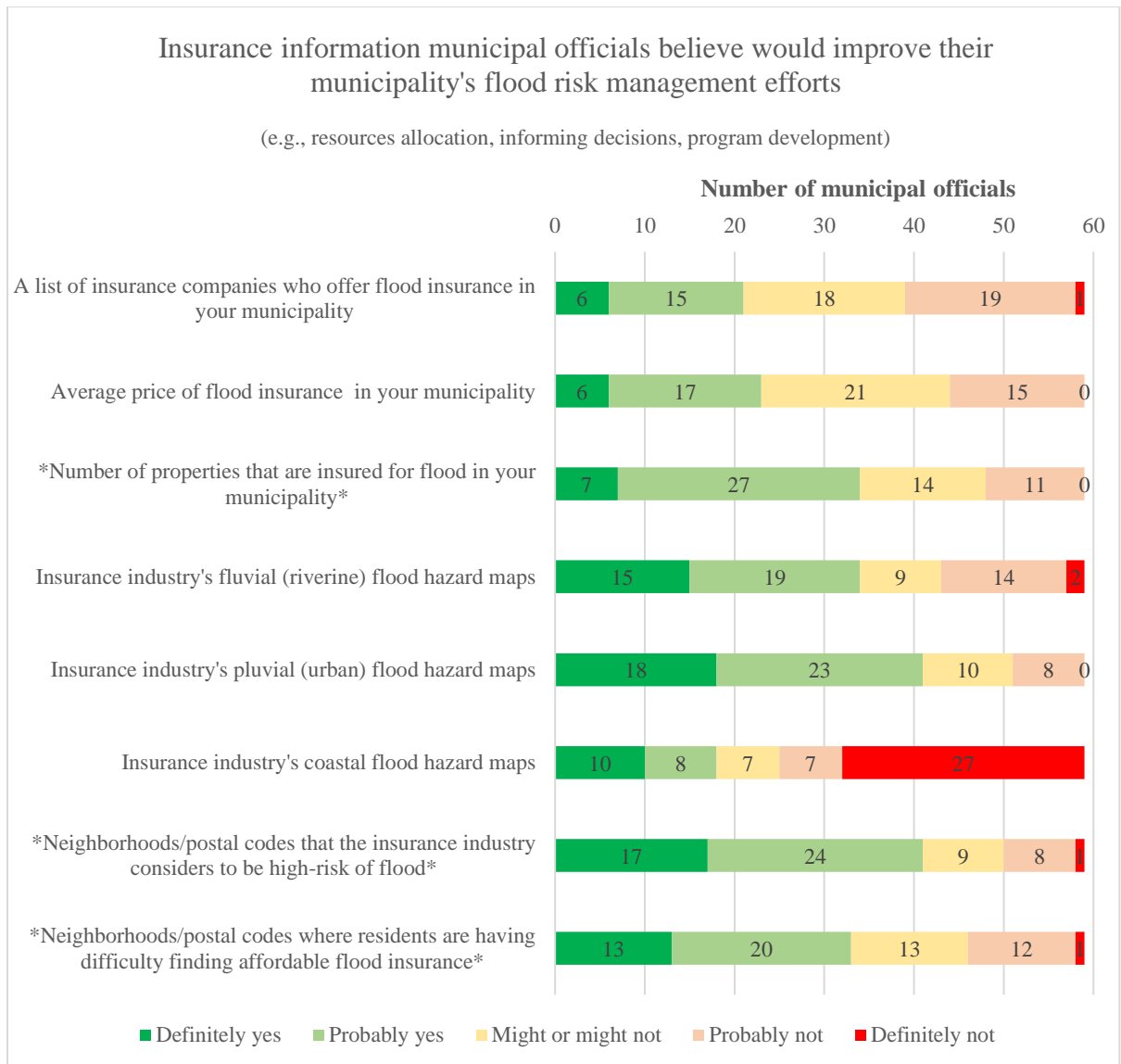


Figure III-3. Insurance information municipal officials believe would improve their municipality’s flood risk management efforts. Datasets highlighted with asterisks (*) indicate that at least one insurance company is willing to provide government officials access to this dataset

Municipal officials were primarily interested in the insurance industry’s pluvial flood hazard maps (41/59; 70%), and neighborhoods and postal codes that the insurance industry considers high-risk for flooding (41/59; 70%). When asked which data they would be willing to

share with government officials, three insurance representatives (3/7; 43%) reported willingness to share some of these data that are of interest to municipalities (highlighted with asterisks in Figure III-3). Two insurance representatives were willing to provide government officials access to data on properties their company has assessed as high-risk of flood. A third insurance representative was willing to provide data on uptake of flood insurance coverage, such as statistics on insurance policies insured for flood damages. However, no insurer was willing to provide government officials access to spatial data used by their company, such as flood hazard zones.

Result #2: Municipalities are willing to share data that could improve insurers capacity to evaluate flood risks to a certain degree

Insurance respondents highlighted datasets that could improve their ability to evaluate property flood risk, such as by calibrating flood models and reducing uncertainty in their understanding of flood risk. Municipal officials reported having access to some of these data and, in some cases, were willing to share them with insurers. Figure III-4 lists the datasets municipal officials are willing to share with insurers which are the same datasets most insurers (at least 5/7; 71+%) indicated would improve their ability to evaluate property flood risk.

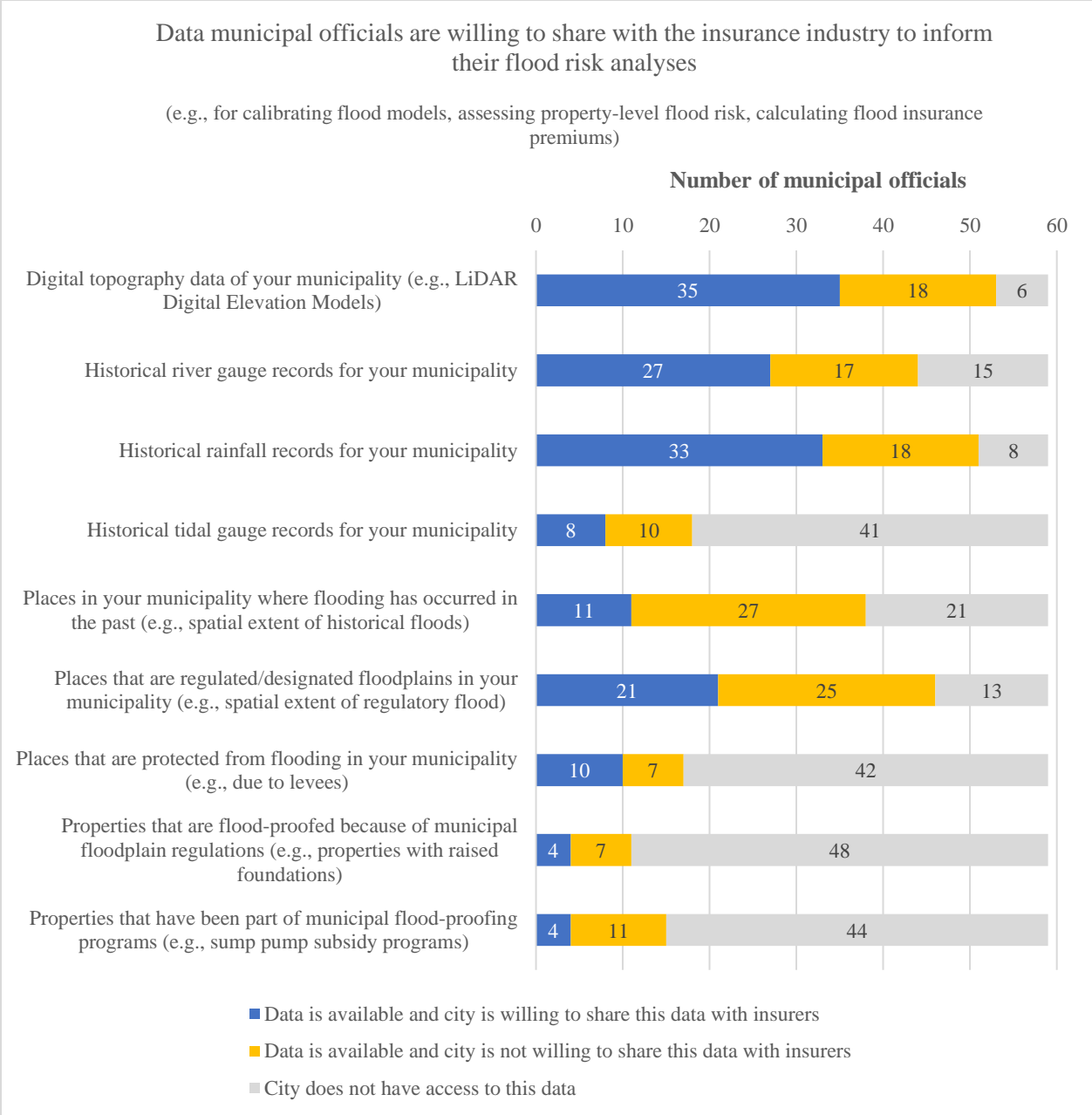


Figure III-4. Data municipal officials are willing to share with the insurance industry to inform their flood risk analyses

Most municipal officials were willing to share some, but not all, their datasets with the insurance industry as only 12 municipal officials (12/59; 20%) were willing to share all their datasets. When available to them, municipal officials were generally willing to share digital

topography data (35/53; 66%), historical river gauge (27/44; 61%) and rainfall records (33/51; 65%), and data on places that are protected from flooding (e.g., due to levees) (10/17; 59%). Municipal officials were less inclined to share data about where flooding has occurred in the past (11/38; 29%), as well as property-specific information, including information on properties that have been flood-proofed through municipal programs (4/15; 27%) and building design regulations (4/11; 36%).

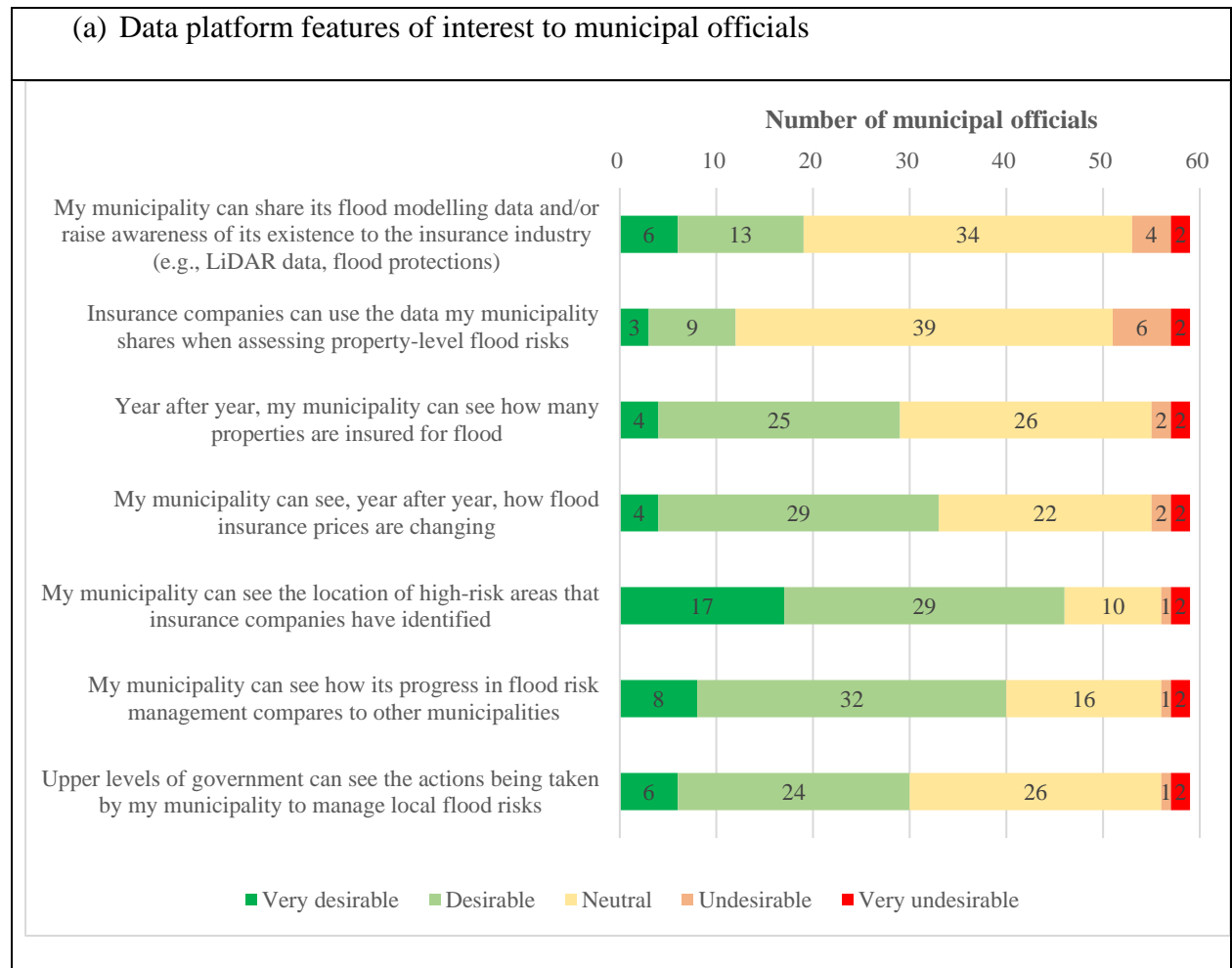
In summary, though there is reluctance to share certain data, the survey results demonstrate there is mutual interest to participate in cross-sectoral data-sharing for improving FRM. Survey results show that datasets one sector is interested in gaining access to, the other sector is capable and willing to provide, such as data on high-risk areas identified by insurers. The following section discusses additional participants' views on the conceptual platform to exchange FRM data.

Participant views on data platform

Result #3: Both sectors favor the data platform

Except for a few, participants generally did not have strong reservations against the proposed data platform (Figure III-5). For example, of the 59 municipal officials, 32 (54%) indicated that they would be “extremely likely” or “likely” to use the data platform for informing municipal FRM efforts. Four municipal officials (7%) indicated they were “unlikely” or “extremely unlikely” to use the data platform, while the remaining 23 municipal officials (39%) were neutral. Similarly, out of the seven insurance representatives, only one representative had strong reservations with the proposed data platform explaining: “I believe most insurers offering flood insurance are not that interested in governments data (governments flood maps are seen as

obsolete, non uniform, political and biased, etc.) and would therefore not act on it in any way. If the question referred to benefits for the governments assuming insurance companies shared their data as well (high risk areas, etc.), then I believe there are potential benefits, but I have strong [reservations].”



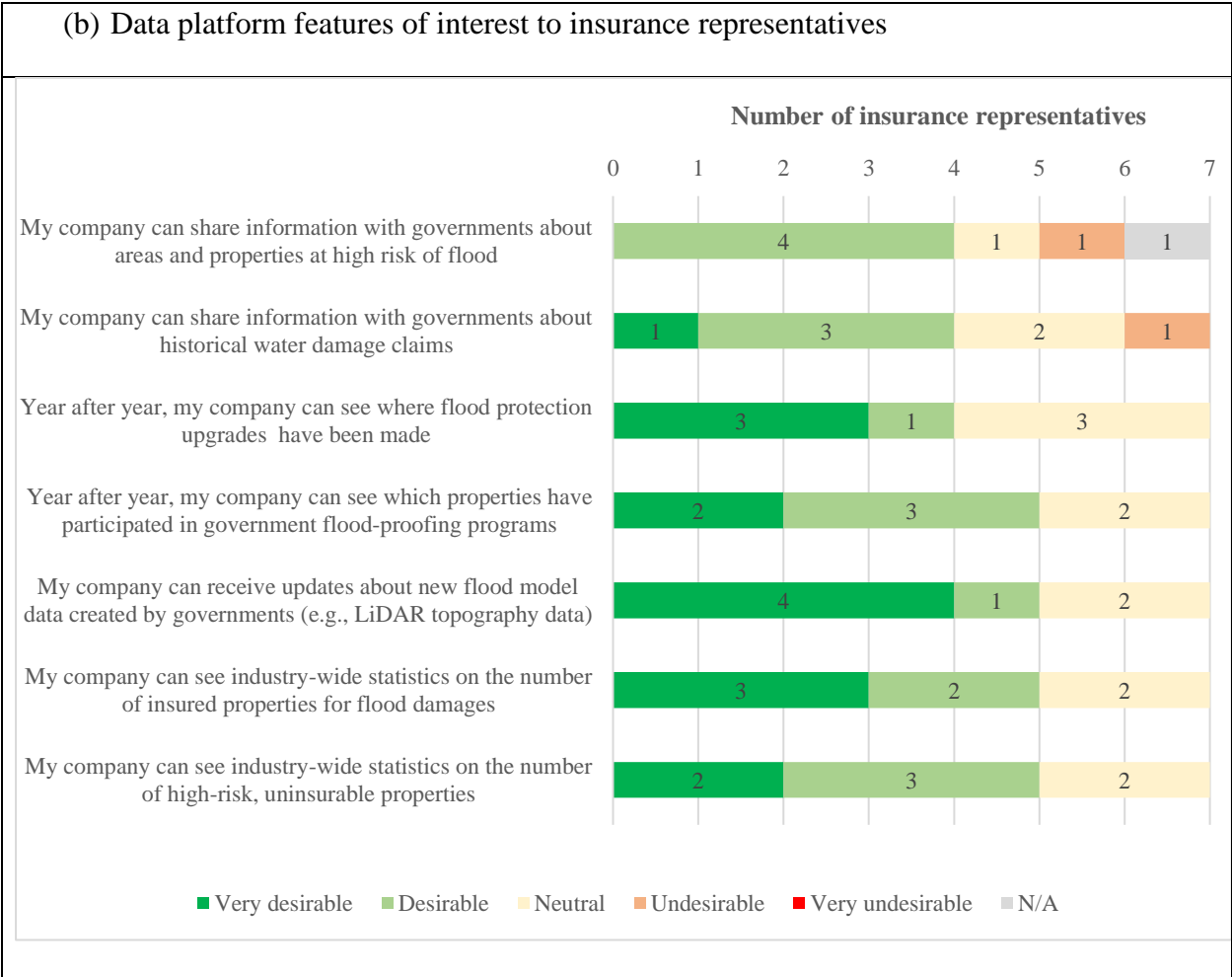


Figure III-5. Data platform features of interest to study participants in the public and private sectors.

Result #4: The data platform is perceived as a tool that could increase municipal capacity to identify and manage flood risk

Municipal officials perceived insurance flood data could be used to inform flood risk mitigation investments and floodplain regulations and zoning (39/59; 66%). One municipal official suggested the data platform would provide “the ability to identify problem areas and determine where infrastructure investments need to be prioritized” while another added that the

“[the data platform] would validate our zoning (conservation areas) and not-constructible [land].” One of the few municipal officials who already had access to insurance flood data (specifically, “insurance industry risks codes at a postal code scale”), recommended that it “would be beneficial for other municipalities [to access these data as well], including data from more than one insurance company”. Insurers agreed indicating a data platform would help government officials “better understand zones where insurance costs are unaffordable or unavailable due to level of risk” and “gain an understanding of the current protection gap, and flood mitigation needs.”

Municipal respondents indicated the data platform could help them gain political support, coordinate and access resources from upper levels of government. For example, one suggested the data platform could help “coordinate flood mitigation efforts between different levels of government and different agencies”, while another two added the platform could help in “public and political education” such as for gaining support for flood protection works. Others indicated that by centralizing FRM data into one system, the data platform could help “avoiding redundancy of data production”, and it would offer an “easier one-stop and streamlined access to data”. In these ways, the data platform could help overcome two common barriers experienced when implementing municipal FRM plans, namely: (1) a lack of support from upper levels of government (e.g., information, financial resources, policy direction) (34/59; 58%) and (2) a lack of resources to implement initiatives or changes (e.g., data, expertise, financial resources) (33/59; 56%).

Result #5: The data platform is perceived as a tool that could increase insurers' capacity to evaluate flood risk which could therefore influence flood insurance availability

Most insurance representatives (5/7; 71%) perceived it is “very probable” or “somewhat probable” the data platform would (1) increase confidence in their company’s flood risk assessments, (2) create efficiencies in the evaluation of flood risks conducted by their company, and (3) promote fair competition between insurance companies (Figure III-6). Insurers admitted the flood models they use, third-party or internal, have data limitations. For example, one participant explained data platform could benefit their company by providing “easily accessible information on flood mitigation measures across Canada [which] would allow [their company] to reflect their effect in our pricing in a more accurate and timely manner.” Another representative similarly explained the data platform would “supplement [their company’s] claims and geographical data to better assess flood risk”.

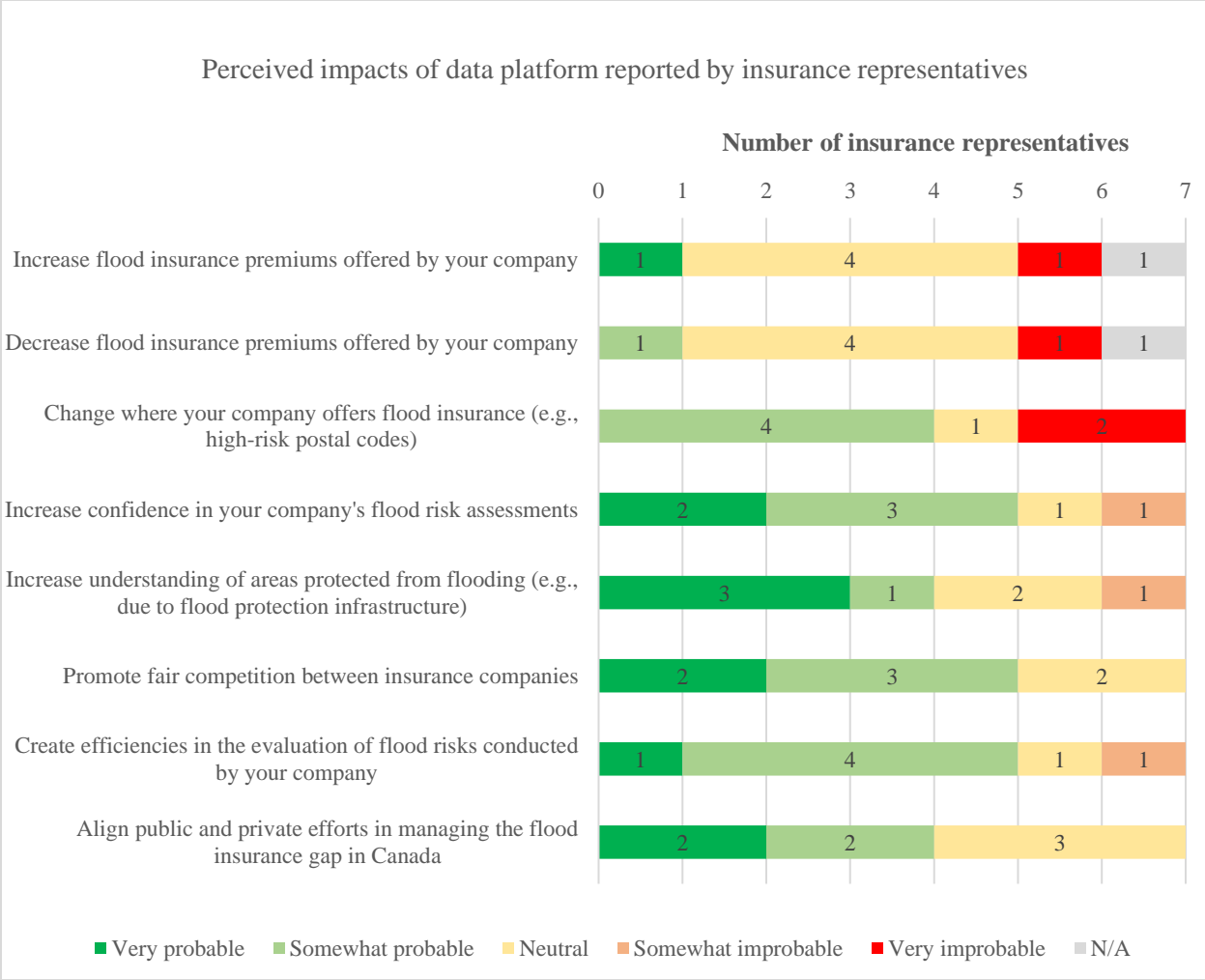


Figure III-6. Perceived impacts of a data platform reported by insurance representatives

Most insurers acknowledged that business decisions regarding flood insurance, such as premium setting, do not “always” factor community- and property-level flood protections. Four insurance representatives indicated they were “moderately confident” that the flood insurance products offered by their company were accurately priced, while a fifth respondent was “somewhat confident”. These answers demonstrate there is an opportunity for the data platform to improve insurers’ flood models.

The survey results suggest that the data platform could impact the availability of flood insurance. For example, four insurance representatives (4/7; 57%) indicated it is “very probable”

or “somewhat probable” the data platform would change the locations where their company offers flood insurance, such as high-risk postal codes (see Figure III-6). One respondent elaborated, “more information regarding flood risk would give us a more precise assessment for each location and therefore would allow us to offer the coverage to more customers.”, suggesting that flood insurance could become more available because of the data platform. Interestingly, one municipality shared they had approached IBC in the past “to determine if insurance rates could be reduced as a result of our infrastructure investments (re sanitary sewer & pluvial risks)”; however, thus far, these efforts were unsuccessful because “IBC has no influence on [insurers’] pricing and so we have to wait for changes in flood history to influence rates”. This finding is further evidence that the data platform ought to directly deal with insurance companies who have authority over risk underwriting. At this time, it appears the data platform could improve availability of flood insurance as insurers become better equipped to precisely identify flood risk; however, there is less evidence to suggest it would decrease flood premiums.

Drawbacks with cross-sectoral data-sharing and future considerations

Result #6: Despite benefits, participants also identified drawbacks with the conceptual data platform that urge careful reflection

Participants from both sectors raised some concerns about the data platform that urge careful consideration for the data platform design and implementation. Among the municipal officials, 30 of 59 participants raised concerns with the data platform, including: data quality issues; data licensing, ownership and privacy issues; costs of platform implementation and maintenance; and concerns regarding raised premiums and loss in insurance coverage for residents. Insurers had similar concerns as municipalities, such as legal and intellectual property issues, costs of

platform implementation and maintenance, data privacy considerations for insurance customers. One added that “caution should be given to how the data would be shared between competing insurers.”, and another stated that there could be “loss of competitive advantage by sharing internal risk assessment.”

Participants from both sectors had ideas about how to overcome these issues. One municipal official asserted the “data [provided by the platform] would need to be properly interpreted...[because] it could then become a burden for local government staff to explain the data source and proper use of data”. Another municipal official with existing access to flood insurance data suggested the data platform should steer away from “too much data, fancy interfaces but not very useful outputs” to prevent mistakes made in the past and specifically referenced MRAT—a tool launched by IBC in 2014 but was discontinued following its pilot stage. They cautioned that the insurance flood data they use has limitations and that it is suitable for “good for high level screening risks if no other hazard modelling exists”. To establish legal terms surrounding shared data, one insurer suggested “to work through a third party to ensure anonymity” and another commented that a governing framework was needed to “to clarify how the information could be used and shared later”. These suggestions warrant future investigation.

3.6 Discussion and conclusions

This study demonstrated that Canadian municipal officials and insurers support a data platform as a tool to foster collaboration that enhances flood resilience, legitimacy, and resource efficiency. Municipal officials regarded the platform as a tool to target flood mitigation investments in high-risk areas that insurers have identified. They also regarded the data platform as a vehicle to access resources and political support needed to implement flood risk mitigation

works, including from higher-level governments. Furthermore, insurers acknowledged that their flood risk analyses could be improved by accessing municipal data on flood defences and other structural measures. They indicated that a data exchange platform could increase their understanding of areas protected from floods, which would influence decisions about flood insurance availability and pricing. Ultimately, the survey findings confirmed that a data platform is a viable solution that should be explored further.

This study also contributed to FRM-related literature by exploring the viability of a tool that could improve flood risk governance. This study employed a novel use of Alexander et al. (2016)'s flood risk governance evaluation framework to first identify entry-points for governance improvement which could then be used to conceptualize a data platform for strengthening flood risk governance. Alexander et al.'s framework was useful to identify specific inter- and intra-sectoral interactions that the data platform could foster for increasing flood resilience, legitimacy, and resource efficiency. The conceptual data platform proposed could be evaluated in other international contexts particularly for nations looking to establish collaborative arrangements between government agencies and insurance companies for holistically increasing flood resilience.

A potential next step for this research is a technical prototype of the data platform, equipped with core features identified as desirable by FRM stakeholders. A technical proof of concept could determine whether the data platform in fact produces the perceived benefits reported in the survey, such as increased public investments in flood protection in high-risk areas identified by insurers, as well as fewer high-risk uninsurable properties. Finally, future studies could explore the idea of a third-party manager to oversee the platform and administer a legal framework that addresses data quality and other concerns expressed by participants.

Chapter 4

Evaluating a public-private data-sharing platform for improving flood insurance availability and affordability

Minano A., Thistlethwaite J., Henstra D. (submitted). Evaluating a public-private data-sharing platform for improving flood insurance availability and affordability. *Journal of Regional Environmental Change*.

Data is an important resource for public and private sector agencies who manage flood risk. Insurance companies use various types of data to assess, categorize and price a property's flood risk, including flood hazard areas and property-specific characteristics. Government agencies, such as municipalities, also use data to identify flood-prone areas and make decisions that prevent and mitigate property flood damages, such as development restrictions and infrastructure upgrades. In a time of rising economic flood damages and future climate risk uncertainties, there are increasing calls to foster flood risk governance integration “through information transfer, coordination, and cooperation” (Gilissen et al., 2016, p. 12). This study presents the Resilience Bridge Platform (“RB Platform”)—a data platform designed to facilitate the exchange of flood risk and resilience data between insurers and Canadian municipal officials. Senior staff and executives in both sectors evaluated the RB Platform and weighed in on the Platform's ability to foster cross-sector collaboration and drive actions that could reduce the number of high-risk “uninsurable” properties. The study discusses the strengths, weaknesses and lessons learned from the evaluation of the RB Platform as a tool to foster integrated governance for effective flood risk management.

4.1 Introduction

In the pursuit of effective flood risk management (FRM), data has become a resource of significant importance for FRM actors (Bernhofen et al., 2022). Various types of data are used for FRM, such as for flood prediction and forecasting, land use policy, infrastructure planning, emergency management and public education (Der Sarkissian et al., 2022; Henstra et al., 2019). For example, LiDAR elevation data is highly sought after by flood modelers to produce accurate estimations of where flooding is most likely to occur (Hooijer & Vernimmen, 2021). Other data such as historical rainfall records, and data on past flood events (e.g., photographs, flooded neighborhoods) are important resources to calibrate and validate flood models and ensure their predictions are accurate and reliable for decision-making (Kutija et al., 2014). The quality of flood model data inputs and outputs can have societal implications, because decision-makers rely on flood hazard data to regulate development and to plan for emergencies (Stevens & Hanschka, 2014; Thapa et al., 2019).

Data are also important for private sector actors, such as insurance companies, which assess a property's flood risk by predicting the likelihood of experiencing a flood and estimating potential loss (Ambiental, 2023). Insurers leverage a suite of data to assess a property's flood risk, such as flood models, spatial statistics (e.g., distance between the property and a river), building footprints and property-specific characteristics (JBA, 2018; Surminski, 2017a). Using these data, insurers make pricing and underwriting decisions, including whether to refuse flood coverage for a property whose flood risk is deemed intolerably high and is therefore "uninsurable" (Calamai & Minano, 2017; Hodgson, 2022). Responding to this demand for flood prediction tools, there are many firms that produce flood models and tools specifically designed to meet the needs of the insurance industry. Meanwhile, governments also use models to assess

flood hazards, but these can differ from models used by industry in terms of their scale of analysis (e.g., global and national-level) and their outputs, such that there are differences in the areas and properties that private models identify as flood-prone versus those identified by government agencies (Minano et al., 2021).

In light of growing flood losses and projections of greater flooding due to climate change, there have been numerous calls across sectors to change current approaches to FRM (McClymont et al., 2019; United Nations, 2015). In particular, there is a recognition of the need for public-private data-sharing partnerships, the co-production of knowledge, and “bridging mechanisms” to “support [governance] integration and coordination” as necessary steps to strengthen FRM (Alexander et al., 2016a, p. 40; LGNZ, 2022; Public Safety Canada, 2022). For example, a recent Swiss Re report stated, “there should be more effort to improve communication of the flood risk realities of different locations within the [insurance] industry, governments and agencies, to help design more effective [risk] mitigation plans” (Bevere & Remondi, 2022, p. 24).

Recent scholarly reviews, however, have found little research on methods and tools that integrate FRM disciplines (e.g., physical and social sciences), overcome knowledge silos, and improve FRM governance processes (e.g., land use and insurance) (Alexander et al., 2016a; Hampton & Curtis, 2022; McClymont et al., 2019). It is argued that better integration would make FRM more effective, as illustrated by Morrison et al., who argue: “the advent of integrated FRM tools is likely to yield more rapid advances in our understanding of linked physical and social influences on flood risk and improved FRM governance” (2018, pp. 299–300).

This paper introduces the Resilience Bridge Platform (“RB Platform”), which was designed to integrate data and facilitate periodic data exchange between insurance companies and municipalities with the goal of reducing the number of high-risk, “uninsurable” properties in Canada. Administratively, the RB Platform is designed as an intermediary that provides users in both sectors with capabilities they do not have independently. The RB Platform provides insurers with a central interface to access otherwise siloed government data, which they can use to improve the accuracy and precision of their flood risk assessments. For municipalities, the RB Platform provides information on properties that insurers consider high-risk and uninsurable, which increases transparency and can be used to underpin local FRM decisions. More broadly, the Platform aims to enable dynamic joint responses that effectively address mutual concerns, particularly the reduction of high-risk, uninsurable properties in Canada. Findings from interviews with key informants who evaluated the RB Platform are presented here, revealing the strengths and weaknesses of this data-sharing tool as a method to promote widespread affordability and availability of flood insurance (i.e., insurability) and to foster governance integration. This study is particularly timely as it was recently announced that the Government of Canada will be establishing a national flood insurance program with a focus on households at high-risk of flooding, and this study’s findings could have implications for that program (GOC, 2023).

4.2 The role of government in private flood insurance markets

Insurance companies and government agencies are inextricably intertwined in FRM. To understand this connection, it is important to first define the meaning of flood risk, from an insurance standpoint, which is the product of hazard, exposure and vulnerability (ICA, 2023).

Hazard refers to the probability of flooding at a given location, exposure refers to the number and value of properties within a flood-prone area, and vulnerability refers to the characteristics of a property that make it more susceptible to flood damage (e.g., a finished basement) (de Moel et al., 2015). These three factors are considered when assessing a property's flood risk, whereby a property exposed and vulnerable to a 500-year flood event (0.2% chance of being flooded in any given year) could be considered as having "low" flood risk, whereas one that is exposed and vulnerable to a 5-year flood event (20% chance of being flooded in any given year) could be considered to have "high" flood risk (Sandink et al., 2010).

Governments can prevent and reduce property flood risk in three main ways, including: (1) investing in public infrastructure, (2) encouraging property-level floodproofing, and (3) land use planning (Sayers et al., 2013). First, the construction of protective infrastructure such as levees and flood walls shield properties from flooding, thereby reducing their risk of damage. For example, the Red River Floodway in Winnipeg, Canada protects residents in flood-prone areas from a 700-year riverine flood (Province of Manitoba, 2023). Second, governments administer programs that incentivize homeowners to install floodproofing devices in their homes, such as a sump pump or backwater valves, which protect properties from flood damage. Lastly, governments can use regulations to set floodproofing construction and redevelopment standards for buildings on floodplains and limit development in flood-prone areas.

Together, these three strategies can prevent that floods cause widespread and frequent property damage. Conversely, failure to take such measures can translate into increased insured economic losses when floods occur, for example, due to a lack of maintenance of flood protection infrastructure and continued construction of floodplains (Andersen & American Society of Civil Engineers, 2007; Verisk, 2022). Therefore, insurers have a clear interest in

lobbying governments to partake in effective flood risk prevention and mitigation.

4.2.1 High-risk properties and the flood insurance dilemma

One barrier to private flood insurance as a tool to manage flood risk is that this type of coverage is often unavailable or unaffordable for properties that insurers consider to be at high risk of flooding (IBC, 2019; OECD, 2016). When faced with high-risk properties, insurance companies may: (1) refuse to insure the property for flood damages, (2) insure the property for an elevated premium that covers potential losses, or (3) cap the maximum compensation that would be paid out when flooding occurs. In some Canadian markets, for instance, it has been estimated that the annual premium to insure a high-risk property could be \$10,000 to \$15,000 (Public Safety Canada, 2022). In cases where maximum payout is capped (e.g., \$30,000 per flood event), property owners are left to cover any repair costs that exceed the maximum payout amount.

The frequency and magnitude of floods are increasing globally as a result of climate change, continued development on floodplains, aging infrastructure, and there is concern that the increasing costs to repair flood damaged property and infrastructure will make flood insurance unavailable or unaffordable for a greater number of properties (J. Lamond & Penning-Rowsell, 2014; Moody's, 2023; Tesselaar et al., 2020; Verisk, 2022). As floods that were once rare occur more frequently, properties that could formerly access insurance could become uninsurable due to the increasing likelihood of flood damage. Likewise, flood insurance premiums could increase to reflect the increased probability of flooding and increased costs to repair flood damaged properties in some regions (Tesselaar et al., 2020).

Historically, the unavailability and unaffordability of flood insurance has been addressed through public-private collaboration, such as the Statement of Principles (SOP) negotiated

between the national government and private insurers in the United Kingdom, which preceded the current Flood Re arrangement. The SOP committed insurers to “continue to offer flood cover to existing domestic property...at significant flood risk [i.e., 75-year flood] providing the Environment Agency has announced plans and notified the ABI [Association of British Insurers] of its intention to reduce the risk of those customers below significant within five years” (Association of British Insurers, 2008). This agreement established a division of responsibility whereby governments facilitate the availability and affordability of flood insurance by reducing property flood risk, such as by building or upgrading flood protection infrastructure (Surminski & Eldridge, 2017). Similarly, through the Community Rating System (CRS), the United States Federal Emergency Management Agency rewards communities that implement flood risk reduction measures by reducing National Flood Insurance Program premiums by up to 45 percent for resident properties (FEMA, 2023). Although different in their design and details, both of these initiatives aim to reduce flood risk to make insurance more available and affordable.

Despite the logical connection between public investments in flood risk reduction and greater flood insurance availability and affordability, governments and insurers often make decisions in isolation of each other. For example, insurers tend to use internal data and methods to base flood insurance pricing and underwriting decisions, and it is often unclear if and to what extent they may be accounting for property- and community-level flood protections in these decisions (Minano et al., 2021; O’Hare et al., 2016; Surminski, 2017a). Establishing a more explicit forum for information-exchange between insurers and government agencies could solidify the connection between government efforts in FRM and greater flood insurance availability and affordability.




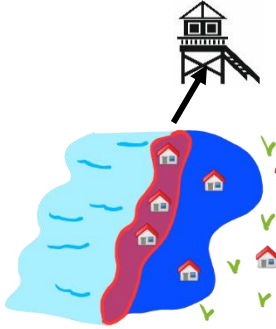
4.2.2 Data-sharing and flood insurance

Data-sharing platforms appear to be promising tools for fostering collaboration between insurers and government agencies in resolving problems of mutual interest (Floodplain Management Australia, 2015; Surminski, 2017a). Data-sharing involves making data owned by one organization available to another, and the *platform* refers to the supporting technology, such as a software application, that enables users to share their data and access the data of other organizations (Wernick & Olk, 2020). Data-sharing platforms could enable new forms of cross-sector collaboration that both reduces flood risk and expands flood insurance availability and affordability.

First, a data-sharing platform could address some of the limitations of insurance industry flood models, which sometimes distort reality or omit certain information, leading to an overestimation of flood risk and a greater share of properties classified as high-risk (Figure IV-1a). For example, in Ireland, “the insurance industry has been accused of treating certain areas of the country that include insurable properties as uninsurable through its use of a geocoding approach [which] allegedly...involves characterizing large areas with the same level of risk, despite recent advances in flood protection...and therefore discriminating against those homes and businesses that stand to benefit from protection measures” (Surminski, 2017a, p. 6). Indeed, in Germany, water authorities found that insurers’ flood maps were based on coarse modelling methods and did not consider flood protection measures, such as (Surminski & Thieken, 2017). Recognizing these technical limitations, German authorities shared the government’s detailed local flood hazard zone mapping, which subsequently reduced the share of high-risk properties from 1.5% in 2008 to 0.65% in 2016 by reclassifying 67,000 homes. These examples demonstrate that technical limitations with flood models used for insurance purposes, such as

low resolution or omission of flood protection measures, can lead insurers to overestimate flood risk.

(a) Address insurers' flood model limitations

| Lack of flood model precision | | Lack of flood model accuracy | |
|---|---|--|--|
| Model – with coarse topography data (flood zone in blue) | Reality – actual flood conditions (flood zone in blue) | Model – omitting community- and property-level flood protections. All properties assessed as high-risk in red. | Reality – buildings in flood zone are on stilts and could be categorized as having moderate flood risk |
|  |  |  |  |

(b) Provide municipalities with additional flood risk information




| Government flood hazard dataset (in purple) | With insurers' flood hazard data (in blue) | With insurers' high-risk properties (in red dots) |
|---|--|---|
|  |  |  |

Figure IV-1. How data-sharing tools could improve weaknesses in FRM

Second, a data-sharing platform could increase transparency about insurers' flood risk analyses, which would be useful for government agencies. For example, insurer flood hazard data on properties considered high-risk and uninsurable could help to target property risk reduction efforts (Figure IV-1b) and enhance government regulatory flood maps, which are often criticized for underrepresenting flood risk. For example, Wing et al. (2018) argued that the U.S. population exposed to flooding is undercounted when using FEMA's 100-year flood zones, calculating that 41 million Americans live within a 100-year floodplain versus the 13 million who live in a FEMA-designated flood zone.

Cases in which insurers have shared data with governments for FRM purposes are sparse, in part because insurers are reluctant to share internal flood risk analyses. As O'Hare et al. (2016) explained, "a result of the privatization of resilience is that information becomes a currency of competitive advantage, effectively an ability to 'price' risk in a more effective manner than their competitors. Insurers noted that their modelling and maps could not be shared, even in aggregated formats, because of the need to retain a commercial advantage and to adhere to data protection conventions." (p. 11). Furthermore, concerns about privacy, protection of commercial interests and sensitivities about how data might be used can all be barriers to data-sharing by organization (O'Hare et al., 2016; Wirth et al., 2021). There is some evidence, however, that insurers are recognizing the potential value of data-sharing. For example, a 2022 Swiss Re report stated that "there should be more effort to improve communication of the flood risk realities of different locations within the industry, governments and agencies, to help design more effective mitigation plans." (Bevere & Remondi, 2022, p. 24). In Norway and Canada, pilot studies in 2020 and 2014, respectively, provided municipalities access to historical claims data in

efforts to assess vulnerabilities in flood protection infrastructure (Climate-ADAPT, 2021; Prail, 2016).

Beyond the data-sharing willingness of partners, there are many legal, administrative, and technological considerations that demand resources and may be too great to justify based on the outcomes of a data-sharing partnership. How to design a data-sharing arrangement that reflects industry and government interests, manages data-sharing barriers and costs, while also producing beneficial outcomes for the public, is a complex process that demands careful analysis.

4.3 Study background and methodology

FRM in Canada is primarily the responsibility of provinces and municipalities (Golnaraghi et al., 2020a), which manage key aspects such as floodplain designation, floodplain development regulations and flood protection infrastructure and maintenance. The federal government also plays a role by partnering with lower tier governments to fund large-scale flood infrastructure works and updating floodplain maps (P. S. Canada, 2018; Infrastructure Canada, 2018). Canada, however, is a federation where FRM activities (e.g., land use, public works) have not generally been coordinated or monitored by a national agency (Henstra et al., 2019).

The 2013 Alberta floods had cascading effects that can still be felt today as its impact demonstrated numerous weaknesses in FRM. One of those weaknesses was that residential properties were not insured for flood damages and that overland flood insurance was unavailable in Canada (Gallichan-Lowe, 2018; Haney, 2017). By 2015, a few large insurance companies began offering residential flood insurance and the Insurance Bureau of Canada (IBC)—Canada’s property & casualty insurance association—commissioned a national flood model to support insurers with product development and pricing (Calamai & Minano, 2017). Concurrently, the

insurance industry became vocal about the inadequacy of government flood hazard data, which were perceived to be low quality, inaccessible and unavailable in a format needed by the industry (Meckbach, 2017; Nadarajah, 2016).

Since 2015, the insurance industry has maintained that between 6 to 10 percent of Canada's housing stock is in areas at high risk of flooding (Al-Shibeeb, 2022; Meckbach, 2016). IBC initially estimated about 1 million high-risk properties, but industry representatives now state that 1.5 million properties are “considered uninsurable for basement flooding, and that figure is increasing” (Chandler, 2022; IBC, 2019). Paradoxically, increased public investments in predicting and reducing property flood risk over the past decade has not reduced the number of high-risk, uninsurable properties (P. S. Canada, 2018; Infrastructure Canada, 2018). Instead, the trend is that flood insurance will become increasingly unavailable and unaffordable, so the insurance industry has lobbied the federal government to launch a public program to deal with high-risk properties (Public Safety Canada, 2022). The 2023 federal budget confirmed the Government of Canada's commitment to “stand-up a low-cost flood insurance program, aimed at protecting households at high risk of flooding and without access to adequate insurance”.

4.3.1 The Resilience Bridge Platform

This study's central hypothesis is that gaps in flood insurance availability and affordability are caused, in part, by the scattered and siloed nature of data. The first problem (Problem #1) is that the inaccessibility of government datasets prohibits the insurance industry from assessing flood risks accurately and precisely, leading them to classify a large number of properties as “uninsurable”. Two recent studies support this contention. First, evidence gathered in a 2022 survey showed that companies offering residential flood insurance inconsistently factor

community- and property-level flood protections in their business decisions (Minano et al. submitted). Second, a 2021 study found that a flood model used widely by insurers identified substantially more properties at-risk of flood than an equivalent government floodplain dataset (Minano et al., 2021). The findings of these two studies suggest that insurance companies could be overestimating flood risk due to the same flood model limitations observed in other countries, such as Germany and Ireland. Lack of access to government flood data could mean insurers are unaware of property-level flood risk reduction projects, because this information is not systematically collected in a national database.

Conversely, the second problem (Problem #2) is that insurance data is not available to government agencies, which prevents them from understanding determinants of flood uninsurability and leveraging their capacity and resources to overcome them. Canadian insurance companies are not required to report to the government on where and why they have classified properties as high-risk of flood. For example, a 2021 survey of municipal officials indicated that few have access to information pertaining to flood insurance, such as the location of high-risk areas and properties that insurers have identified in their jurisdiction (Minano et al. submitted). By interviewing senior staff in insurance companies and municipalities, this study explores these two problems and assesses whether a data-sharing platform could enable new collaboration between insurers and municipalities to expand flood insurability.

Platform design and development

The Resilience Bridge Platform (or RB Platform) was designed as a Web-based tool to collect, curate, and manage data from municipalities and insurance companies via a central data management system. At a high-level, the RB Platform was conceptualized as a data intermediary

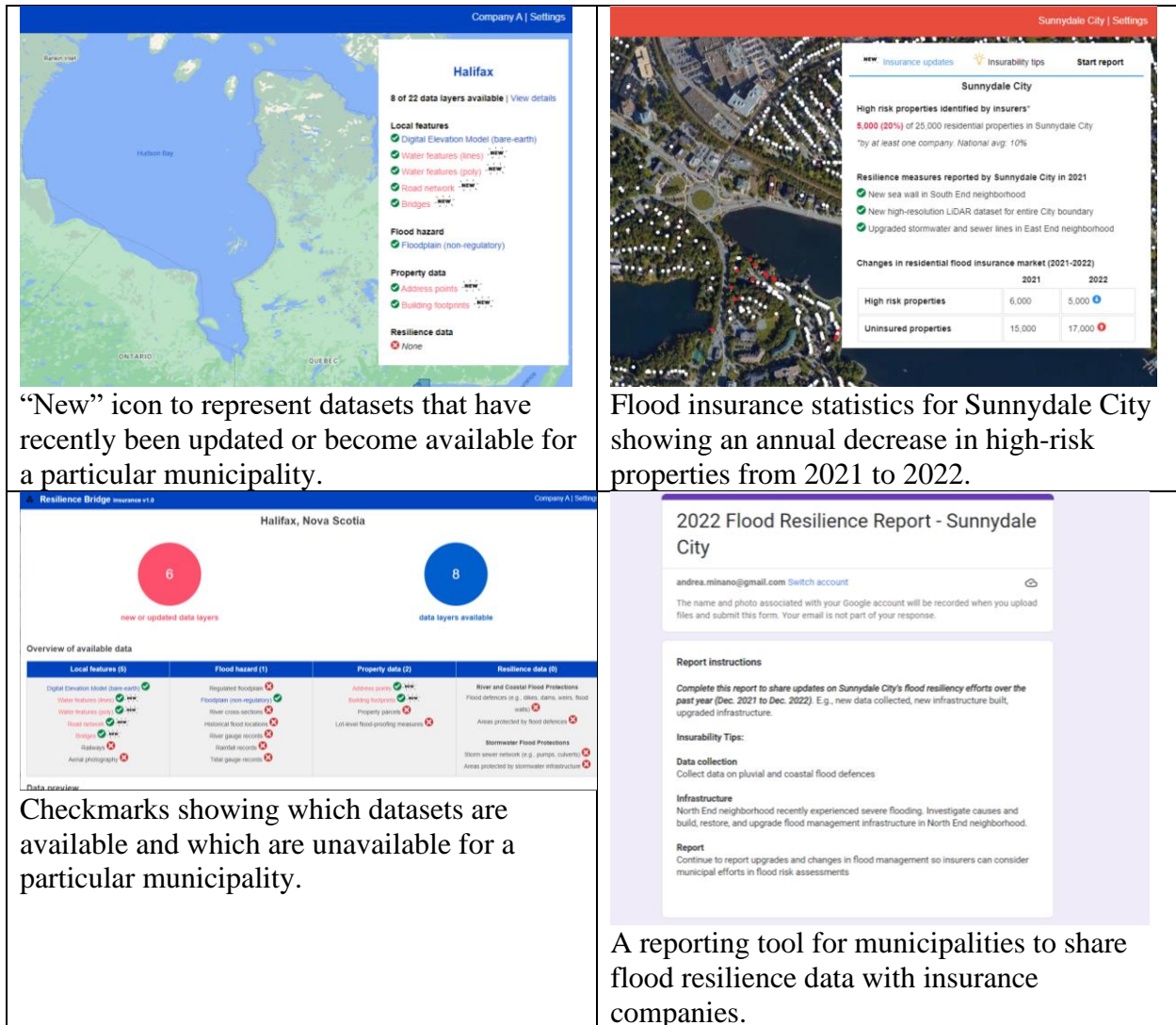
that would establish a line of communication between insurance companies and municipalities (Figure IV-2a). This Platform was designed to achieve three Objectives:

- (1) Make government FRM data available to insurers to strengthen their capacity to assess property flood risks accurately and precisely
- (2) Illuminate scope and determinants of flood uninsurability to inform municipal FRM decision-making
- (3) Facilitate cooperation between insurers and municipalities to expand flood insurability in a sustained manner



(a) The role of the RB Platform as a “bridge” between two sectors

| Interface #1 – for insurance companies | Interface #2 – for municipalities |
|--|---|
| <p>National data index displaying municipalities in Canada. Each municipal boundary can be clicked on by the user to see which types of flood risk and resilience data are available for a given municipality.</p> | <p>Map of Sunnydale City displaying properties insurers consider high-risk of flood in red. This is a mock-up using dummy data.</p> |



“New” icon to represent datasets that have recently been updated or become available for a particular municipality.

Flood insurance statistics for Sunnydale City showing an annual decrease in high-risk properties from 2021 to 2022.

Checkmarks showing which datasets are available and which are unavailable for a particular municipality.

A reporting tool for municipalities to share flood resilience data with insurance companies.

(b) Technical capabilities of the RB Platform

Figure IV-2. Conceptual overview and design of RB Platform. Appendix C includes additional images of the RB Platform.

To achieve Objective #1, the RB Platform provided insurance companies a user interface (Interface #1) where public and internal government data were centralized in one national data index (Figure IV-2b). Interface #1 displays a map of Canadian municipalities and showcases which datasets are available and unavailable for a given municipality. These datasets were grouped into four categories: local features (e.g., digital elevation models), flood hazard (e.g.,

floodplain data), property data (e.g., building footprints), and resilience data (e.g., river flood protection data). Interface #1 also contained a “new” icon for datasets that have been recently updated by a municipality. It was intended that Interface #1 would help insurers find data of interest more easily as well as ease the tracking of FRM initiatives undertaken by different municipalities across Canada.

To achieve Objective #2, the RB Platform provided municipalities with a user interface (Interface #2) where they could see a map of properties that insurance companies identified as high-risk. A mock-up community called “Sunnydale City” was created since insurance data were unavailable to the researcher. Interface #2 showed a map of Sunnydale City alongside statistics on attributes such as the number and proportion of properties insurers consider to be at-high risk. It also provided a list of “resilience measures” that Sunnydale City had made in the past and how the number of high-risk properties had declined in a one-year period (i.e., 2021 to 2022) as a result. Interface #2 included a reporting tool that could be used by Sunnydale City officials to report new resilience measures implemented over the last year (i.e., 2022). It also included tips from insurance companies on what Sunnydale City could do to further expand flood insurability. It was intended that Interface #2 would clarify actions that municipalities could take to promote flood insurance availability and affordability and increase transparency about how municipal investments in FRM could result in fewer high-risk, uninsurable properties.

If implemented, Interface #1 and Interface #2 would collectively achieve Objective #3 by facilitating cooperation between insurers and municipalities to expand flood insurability in a sustained manner. For example, it would enable insurers to improve their flood risk assessments by accounting for recent improvements in municipal flood protection, while municipalities could see how their flood protection investments are reflected in insurance pricing and underwriting

decisions. With these potential benefits in mind, this study sought to assess the viability of the RB Platform based on whether public and private stakeholders would use the platform in practice.

Platform evaluation protocol

The RB Platform was evaluated primarily via interviews, after which participants could complete an optional feedback survey. Interviewees were selected from a list of 59 municipal officials and 7 insurance representatives who completed surveys in 2021 and early 2022 for a related study (Minano et al. submitted). The 59 municipal officials represent municipalities in which about 30% of Canada's population resides. The 7 insurance companies are among 16 that offer residential flood insurance (IBC, 2019). Interviewees comprised primarily senior staff (e.g., directors and managers). Municipal officials generally managed engineering, public works, planning or environment departments, and insurance representatives worked primarily in actuarial science, personal property insurance, and hazards modelling.

Out of 59 municipal officials, 22 were selected for interviews who had earlier expressed interest in seeing insurer-identified high-risk areas (n=15), already had access to flood insurance data (e.g., neighborhoods or postal codes the industry considers at high-risk of flood) (n=6) or had collaborated with the insurance industry in the past (n=1). Those who had an interest in flood insurance data were selected to better understand how they foresee these data benefiting their municipality. Meanwhile, those who had used flood insurance data were selected as they could provide insights on the utility of these data for other municipalities, and whether they would recommend other municipalities use flood insurance data. All 7 insurance representatives were targeted for interviews.

Interview questions and format

Interview participants were recruited by email between October and December 2022. Interviews were 60 minutes in length, were conducted remotely via video link and were audio and video recorded. All interviews were structured to include (1) an introduction, (2) a demonstration of the prototype and (3) closing thoughts. A presentation and a live demonstration of the RB Platform were used to illustrate its capabilities and facilitate discussion.

Interviews were semi-structured to evaluate the RB Platform using three criteria: scope, feasibility, and effectiveness. To evaluate scope, participants were asked questions about the availability of data and how data are used by their organization, as well as problems that stem from data silos (i.e., Problems #1-2). For example, insurance representatives were asked, “how do you currently keep track of areas where upgrades in flood protection are happening across Canada?”. To evaluate the feasibility of the RB Platform, participants were asked questions about their willingness to share data to support decision-making in another sector. For example, municipal interviewees were asked, “are you interested in sharing municipal data with insurance companies for informing their flood risk analyses?”. To evaluate effectiveness, participants were asked to comment on the degree to which they perceived that the RB Platform would achieve its objectives. For insurers, those objectives included whether the RB Platform would be likely to improve access to high-quality data used for flood risk detection and evaluation, and whether these data would change where their company offers flood insurance and how flood premiums are priced. For municipal interviewees, those objectives included whether the RB Platform would improve access to decision-useful flood information, increase their municipal capacity to manage flood risks, and produce benefits for the public. The complete interview protocols are found Appendix D.

4.4 Results and discussion

4.4.1 Study participants

Interviews were conducted between November 2022 and January 2023. Ten representatives (n=10) from five insurance companies participated, nine of whom were interviewed and one of whom watched a video tutorial of the prototype and answered the feedback survey. In total, six insurance representatives completed the feedback survey.

Eighteen representatives (n=18) were interviewed, representing thirteen (59%) of the 22 municipalities that were targeted for this study (Table IV-1). Among them, thirteen (72%) had leading roles in their municipalities, including department directors and managers. Most were engineers (11/18; 61%) who manage the construction and maintenance of municipal infrastructure, including storm and sewer networks and river flood protections. All had relevant expertise relevant for this study, such as planning, climate change, emergency management and municipal risk management and insurance. Five municipal interviewees also completed the feedback survey.

Table IV-1. Municipalities represented in this study, by province

| By province | Number of municipalities whose participation was requested | Number of municipalities who participated in this study |
|---------------------------|---|--|
| Alberta | 2 | 1 |
| British Columbia | 3 | 1 |
| Manitoba | 1 | 1 |
| New Brunswick | 2 | 1 |
| Newfoundland and Labrador | - | - |
| Nova Scotia | 2 | 2 |
| Ontario | 10 | 7 |
| Prince Edward Island | - | - |
| Quebec | - | - |
| Saskatchewan | 2 | - |
| Total | 22 | 13 |

In total, 28 participants were part of this study, 10 representing the insurance industry and 18 representing the municipal public sector. Their views on the RB Platform are presented in the next section.

4.4.2 Platform evaluation results

Participants confirmed that lack of access to municipal data limits insurer awareness of investments in flood protection and other government initiatives happening across Canada. Interviewees suggested that municipal officials are generally unfamiliar with the criteria insurers use to assess a property as “high risk”. A few municipal officials reported that their community has already attempted to negotiate better flood insurance rates for their residents but have received a muted response from the insurance industry, which confirms there is a “missing link” between the actions taken by municipal governments in FRM and flood insurance decisions.

Municipal interviewees questioned the degree to which the RB Platform would make flood insurance more available and affordable, because gaining access to new data does not necessarily mean the data will be used to change insurance pricing and underwriting decisions. Municipal officials also expressed concern about how their data could be interpreted by insurers, demonstrating reluctance to share information that could lead to contraction of insurance coverage or more expensive premiums for residents. In the next section, the views of stakeholders are used to sketch out a potential alternative pathway forward that could address these concerns and also achieve the objectives of the RB Platform.

Strengths of RB Platform

Data silos are likely preventing insurers from accurately and precisely assessing property flood risk

Insurer interviewees stated that the fragmented patchwork of government flood hazard data is a barrier to assessing property flood risk. In particular, interviewees cited difficulty in finding LiDAR elevation data, land parcel data, property characteristics (e.g., first floor elevation of a home), and historical flood losses. Moreover, finding data on flood protection infrastructure is particularly challenging for insurers. One representative indicated that keeping track of infrastructure upgrades happening across “cities and geographies” is one of the “biggest challenges” and that this continuous search is in “in some ways...out of our expertise”. A representative from another company echoed the same sentiment, stating, “that's the part that's difficult for us as insurers to sort of keep it on top of”, while a third company representative described getting access to data about a privately-owned dam through personal connections (i.e., “friends of friends”). They later added in reference to the RB Platform’s national data index, “having a single point [for data searching] that we can radiate from...that would be really useful” because “we cannot be talking to every city all the time” and it would ease the process of knowing which data is available and which is unavailable for a given city or region.

Insurers reported that they track changes in flood infrastructure through their own manual searches (e.g., Google; contacting municipalities), by relying on third-party flood modelling firms for updates, and by drawing insights from insurance brokers and agents working in communities. A few municipal officials confirmed they had been contacted by insurance companies who specifically asked about municipal data on flood hazards and infrastructure, but these types of interactions are sporadic. For example, one municipal official explained their most

recent interaction with an insurance company was “a few years ago” who was asked about their dike system and the level of protection the dike system provides, but that it had been “quite a while since I’ve had an inquiry”. Municipalities also stated that municipal asset data that insurers consider “flood protection data”, such as pipe’s age of construction and maintenance history, is collected for internal municipal use and are usually not published in public data repositories. Therefore, unless insurers periodically contact individual municipalities and can persuade them to share these data, then they are unlikely to have a complete understanding of upgrades to municipal flood protection infrastructure, such as increased capacity of drainpipes, which could lower flood risk in a community.

In addition to conducting their own research, insurers learn about infrastructure upgrades through third-party flood model updates, and through insurance brokers and local insurance agents who flag pricing discrepancies and customer complaints. Regarding third-party flood models, one interviewee stated, “we’re hoping that these models incorporate the new dikes or the new walls...but it’s hard to be on top of everything”. Insurance brokers also flag client-provided insights, which typically involve arguments that “they should have a discount on their flood insurance [because] there has been some infrastructure work near their home”. Such demands prompt insurers to validate the client’s insight by seeking government documents (e.g., engineering design documents) or contacting third-party flood modelers for an explanation. For example, another insurer explained that brokers can highlight that “this pricing for personal lines flood in such area is terrible, you’re way off the market...and we may call the [flood modelling firm, and ask], do you know something about this municipality? Because according to your model, they’re terrible, and they’ll go...we’ve updated the model, we can sell it to you.” Current practices suggest that it is likely that public flood infrastructure investments are not being

consistently accounted for in insurers' flood risk analyses and that there is likely a time lag between the construction of a new piece of infrastructure and its incorporation into insurers' flood risk analyses.

There is a 'missing link' between municipal FRM decisions and flood insurance

The interviews confirmed that municipalities rarely have access to data about flood insurance and do not understand the reasons insurers use to classify a property as 'high risk'. Among the 13 municipal interviewees, only three had access to flood insurance information for their community. Specifically, one had access to a well-known flood hazard dataset that insurers use to assess property flood risk, another had access to residential flood insurance claims data, and the third had access to 6-digit postal code data that classified levels of "sewer backup risk". The latter two interviewees confirmed these data had been obtained by the city four years ago or longer. These findings confirm that it is rare for municipalities to have access to data insurers use to identify flood risk (e.g., third-party flood models) or the output of industry risk analyses, such as data on areas and properties that companies classify as high-risk of flood. Although most expressed interest in the RB Platform as a means to see the location of high-risk areas identified by insurers, they indicated that understanding the reasons why these properties were classified as "high risk" would be imperative to inform municipal decision-making.

It is evident that some municipalities have pursued data-sharing with insurers, especially those advocating for better premiums for their residents after investing in flood infrastructure upgrades. Conversely, municipalities that have proactively attempted to share their data or insights with the insurance industry have received a muted response. One municipal official explained:

“We’ve had some luck talking to different insurance providers about the [flood] mitigation that we’ve put in, but some have been interested and some just haven’t. And when we’ve talked to them about incorporating our more accurate [flood] maps...they’ve said no, they can’t do that [because] they need to use their same consistent processes and mapping across, you know the province or the country”.

An official from another city reported that they had approached IBC to explain flood protection investments some years ago, but told that “it's great we're doing this [flood protection] program...[however,] they don't have an influence over the pricing that insurance companies have, and they didn't have a platform to...share any of our upgrade data”. Another city official echoed a similar experience with IBC, reporting that they were told, “nice that you guys are doing these investments. We'll see first in how that is reflected in the claims...then we'll consider in possibly lowering rates where there are demonstrated lower damages incurred...so from our perspective it's not fair.”

In summary, these findings suggest that the RB Platform’s ability to integrate government data into one central system could help insurers find data more efficiently and could increase visibility of available data resources. They also confirm that the RB Platform could fill in the “missing link” to “help the conversation between municipalities and insurance industry”, as echoed by a study participant.

Weaknesses of RB Platform

The greatest weaknesses of the RB Platform are that it does not appear it would be an effective tool to alleviate flood insurance availability and affordability, particularly if it is implemented in

isolation from other strategies, and that its adoption will face several practical challenges particularly to gain buy-in from municipalities to participate in data-sharing with insurers.

Increased data access is not enough for insurers

When asked if they perceived that the RB Platform could change where their company offers flood insurance or influence the premiums charged to clients, insurance interviewees had mixed responses. Some reinforced that gaining access to data does not necessarily mean it will be used for business decisions. One industry representative explained they would first need to see how the data performed over time in order to assess its quality. Generally, insurers referred to the need for “consistent” and “reliable” data and expressed doubt that governments could provide them. One insurer indicated that “there are very few areas of flood defences in Canada that are of high quality. If you compare that to something like the Netherlands that has a very focused governmental stance on public flood defences, they would be more reliable to understand how and why those defences would protect from...a certain level of event”. They added, “ideally, for us to consume it [the data], it would have to be on a polygon kind of basis so that we understand the areas that are protected based off of the flood zone and connect it back to that flood zone that’s providing that level of protection. But the challenges that we have right now is that there’s lots of flood protections in Canada, there’s very few that are of high quality.” A representative from another company expressed a similar sentiment, asserting, “the flood maps in Canada are poor, old...they’re not consistent across different areas”. A third company representative indicated that “if we don't have good information on a mitigation structure or flood defense, we don't include it. If we're not able to find good information on it, we play on the safe side and we don't include it, or we include it, but we tone down its supposed efficiency.” These comments suggest that even if municipalities were to share their protection data, insurers

might still decide not to use them, on the basis that municipal data is inconsistent or that they do not consider municipal data as a reliable source for decision-making.

Additionally, even if new information becomes available to insurers, such that an area or property could be re-classified from a “high risk” category to a “low risk” category, there may still be hesitation to adjust premiums to reflect this. As one insurance interviewee explained, “these [cases] are always tricky to manage in house...we are very aware that it’s not a good signal like client-wise, ‘why then were you charging me so high last year and now?’”. A more promising approach for insurers might be to re-consider their pricing when a broker and client raise the issue rather than when they stumble upon new information (i.e., “your pricing is completely off in this particular area, look, they’ve built walls, you don’t have the latest information”).

Negative consequences for municipalities to engage in data-sharing with insurers

Municipal interviewees expressed a common concern that sharing data with insurers could have negative consequences for residents. For example, one municipal official said, “we’re kind of more of the vulnerable party in this relationship... what they do can impact us more than what we do impacting them.” Specifically, several interviewees worried that providing flood hazard and defence data to insurers could prompt them to deny coverage or raise premiums. As one official stated, if insurers “use some of that information to deny insurance to large swaths of communities that you know up to now have been insurable...it could be really damaging”. Another municipal official stated, “worst case scenario occurs and we share this data and it directly relates to the homeowner losing coverage that they had previously”. Another, lesser concern was that some residents approach municipalities for advice about how deal with a flood in their home and to protect their property from future flooding—personal information they do

not anticipate a municipality in sharing with a third-party. Clearly there is some skepticism among municipal officials about the benefits of a data partnership with insurers, when weighed against the possibility that it could harm residents through loss of insurance coverage or higher premiums.

Important findings and a pathway forward

Although this evaluation of the RB Platform prototype revealed some weaknesses, it also uncovered two important findings. The first important finding is that there is significant ambiguity around the reasons why some properties are considered “high risk” by insurance companies and the scope of the problem. Among competing insurance companies, there are differences in the operational definition of “high risk”, as confirmed by one insurance representative who stated, “it will not be apples to apples if you ask five different insurers where which are the high risk properties in this area”. It is also apparent that the slate of properties considered “high risk” by insurance companies changes periodically. All participating insurers indicated that updates to the flood models they use result in re-classification of the risk level assigned to specific properties, which can sometimes cause a change from a low to a high-risk category and vice versa. One company indicated these model updates happen frequently, with at least five updates since 2015. Meanwhile, some municipalities have been approached by residents looking for solutions to loss of their flood coverage, such as by installing property-level protections or challenging the boundaries of the insurer’s flood zone. In summary, it is imperative to understand why properties are categorized as “high risk” by insurance companies and to find a way to transition properties from being “uninsurable” to “insurable”.

Formalizing a process of appeal

Beyond the data-sharing RB Platform, flood insurance availability and affordability could be expanded by establishing a formal appeal process whereby the owner of a property labelled as high-risk or is being charged an unaffordable premium could seek advice for remedying this issue. Such a process would require insurance companies to justify their risk classification, and the property owner could appeal the insurers' decision. This is already happening in Canada to a degree, but it occurs informally and piecemeal. For example, one municipality indicated that its home floodproofing subsidy program had enabled some homeowners to access flood insurance coverage. Similarly, an insurance interviewee reported seeking municipal engineering design documents to validate clients' arguments for a reduced flood premium in light of municipal investments in new flood protections. Another insurance representative indicated that "the customer...[is] blind to the mapping that we do use...that's a piece that's definitely missing for me, is consumer education on what their risk is". They later added, that aside from municipalities, "consumers...at the end of the day are the ones that can... do things to help mitigate [flood risk] and make themselves more insurable". This appeal process could be mediated by a provincial or federal government body that tracks cases and documents experiences and outcomes to inform public policy.

The second important finding is that insurers perceive that governments are not a reliable source of flood risk information and are ineffective at reducing property flood risk. Statements from insurers such as "the flood maps in Canada are poor, old...they're not consistent across different areas", and that "I think governments, municipalities don't necessarily have a view [of flood risk] at all today. So I think the data, if we provided that would give them...a clearer picture where there are severe risks", show that there is a perception that insurers' data is more

reliable and complete than that used by government agencies. This perception is not unique to the insurance industry as journalists in 2019 published articles with similar sentiments, e.g., “poor flood-risk maps, or none at all, are keeping Canadian communities in flood-prone areas” (McClearn, 2019). The perception of government inadequacy in FRM spans beyond data-related issues. One insurer explained, “municipalities quite often they have, not all the time, but they tend to have perverse incentives regarding flood management, whereas they are living, they are surviving through... property taxes...they tend to be incentivized to look the other way and minimize and disregard the actual flood risk, or at least for the longest time they had”. And this perception, at least in part, lies on not being able to track changes and investments in FRM across Canada, “if we start seeing a lot less of those red zones and we start seeing additional resilience features being added, red zone starting to go down, then I would say I have a level of trust that they're doing things to incrementally improve the flood risk in those zones”.

Addressing the perception of government unreliability

FRM in Canada is largely the responsibility of 10 provinces and more than 5,000 municipalities. This governance complexity undoubtedly makes it difficult for insurance companies, which operate nationally, to appreciate the many FRM initiatives and investments occurring across the country. It is evident from these interviews that municipal officials are updating their flood models, investing in flood protection infrastructure and responding to a sense of urgency to address their community’s flood risk. A national data index like the RB Platform could overcome this lack of visibility of government progress in FRM, which could be further developed to index all publicly available data on local features, flood hazards, exposure and resilience in one central public website. Participants mentioned some other initiatives that could support a data collection process of flood protection infrastructure, such as Ontario’s Asset

Management Regulation that requires all municipalities to report on the “percentage of properties in municipality resilient to a 100-year storm” and the “percentage of the municipal stormwater management system resilient to a 5-year storm” (Province of Ontario, 2021). In conclusion, there is a need to address the perception that governments are unreliable partners in FRM, which could be demonstrated through greater transparency of FRM activities (e.g., efficacy of floodplain regulations, flood protection upgrades) and data integration.

4.5 Conclusions

This study confirmed the presence of two problems that stem from governance fragmentation, and which appear to act as barriers from promoting greater flood insurance availability and affordability. First, the absence of a central data repository that records and tracks flood infrastructure efforts (e.g., for riverine, pluvial FRM) happening across Canada pose difficulties for insurers to become aware of incremental changes to flood protection. This subsequently prevents or creates a time lag to reflect public investments in flood insurance pricing and underwriting decisions. Second, the lack of transparency about how insurers conclude a property is at “high risk” of flood (e.g., the cause of flooding, the flood return period used) does not lend itself to unpacking the problem and effectively leveraging government resources to help residents transition from a high to a lower risk category. Such as by providing additional information about how a property is protected from flooding that insurers may have been unaware of, or by using insurance insights to inform future flood infrastructure plans. The interviews also confirmed that flood model updates and new information can lead insurers to re-assess the flood risk levels assigned to their clients. However, given the lack of transparency about this risk re-classification process, it is difficult to know where the high-risk “uninsurable” properties remain at present time.

The RB Platform was designed as a tool to foster governance integration by “bridging” actors that are currently working largely independently from one another (e.g., among competing insurers) and across sectors (e.g., municipalities and insurers). Though there were some weaknesses to the RB Platform, aspects of it do appear beneficial for overcoming governance fragmentation. For example, the national data index can ease the process of discovery of available government data repositories that are currently found across many municipal open data websites. However, this study revealed that gaining access to new data does not equate that insurers will immediately change premiums or re-adjust a property’s flood risk classification since they may question the validity and quality of the data, the data may not be consistent with their internal processes, or they may need to see fewer claims to validate the data.

In 2023, the Government of Canada revealed its intention “to stand-up a low-cost flood insurance program, aimed at protecting households at high risk of flooding and without access to adequate insurance” (GOC, 2023, p. 136). As a parallel strategy to this program, the three levels of government could partner to develop a national flood defences database that could be used by residents to advocate for lower flood premiums and (re-)gain access to flood insurance coverage. This could also encourage that the national flood insurance program focuses on those who truly cannot find flood insurance coverage after exhausting all options. Given that the IBC expects the number of high-risk properties to increase, and internationally there are discussions for insurers to exit certain high-risk markets due to low profitability (Al-Shibeeb, 2022; Moody’s, 2023), it is becoming increasingly important to solidify the relationship between flood risk prevention, mitigation and insurance to ensure flood insurance remains available and affordable in the long-term.

Lastly, this study responded to gaps in the literature and calls from the international community to establish public-private data-sharing partnerships for supporting effective flood risk management (Bevere & Remondi, 2022; Gilissen et al., 2016). The methods presented here can be considered a governance integration tool as demanded by scholars such as Morrison et al. (2018). The RB Platform could be used to facilitate discussions about data-sharing in other international contexts where public-private data-sharing partnerships are being considered (e.g., New Zealand) and to better understand if these types of partnerships will in fact lead to beneficial outcomes for society (LGNZ, 2022).

Chapter 5

Dissertation Summary and Conclusions

5.1 Summary of dissertation findings

The three studies that comprise this dissertation investigated several research questions to identify the strengths and weaknesses of Canada's governance approach to FRM and opportunities for improvement. The primary focus of this dissertation was the opportunities to enhance interconnectedness between the P&C insurance industry and the public sector, specifically Canadian municipalities. The following sections outline the objectives of each study and describe how these objectives were met.

5.1.1 Study #1: A comparative analysis of government and insurance geospatial data for identifying properties at risk of flood (*Chapter 2*)

Study #1 research questions (RQ): RQ1: How similar are insurer and government views of flood risk? RQ2: What are the potential societal implications of divergence in these views of flood risk?

Objective 1: Map, quantify and compare flood-prone regions and properties by leveraging geospatial data used by government agencies and insurance companies for flood risk identification in three Canadian cities (Halifax, Toronto, and Calgary).

Objective 2: Based on the results of *Objective 1*, discuss the implications that conflicting views of flood risk could have for addressing flood insurance unavailability and unaffordability issues in Canada.

The first study compared the location and number of residential properties that municipalities consider to be in flood hazard areas for the purposes of FRM with those referenced by insurance companies for underwriting and premium pricing decisions. To the author's knowledge, this was the first study published in a peer-reviewed journal that compared systematically the contrasting views of flood risk produced by data used by insurers versus data used by government officials. The study found that out of 933,468 residential properties in three Canadian cities (Halifax, Toronto, and Calgary), 16,239 (1.7%) were located in government-identified flood risk areas (i.e., 100-year return period), whereas 51,603 (5.5%) were identified in equivalent areas by an industry flood model (**RQ1; Objective 1**). The study discussed how a lack of transparency about how insurers assess flood risk diminishes government awareness of these higher risk flood areas and undermines the adoption of appropriate policy responses (**RQ2; Objective 2**). The study proposed the development of a data management system to integrate government and industry flood hazard data to establish a common understanding of the "flood problem" and enhance collaboration between public and private actors to reduce and manage the number of residential properties at high-risk of flood.

5.1.2 Study #2: Conceptualizing and evaluating the role of a data platform for strengthening flood risk governance (Chapter 3)

Study #2 research questions (RQ): **RQ1:** Is there an appetite among municipalities and insurance companies to integrate their flood risk data into a shared data platform to inform FRM efforts and decisions? **RQ2:** What should a data integration platform do to reflect the interests of municipal officials and insurance representatives?

Objective 1: Survey Canadian municipal officials to assess the extent to which they have access to flood insurance data (e.g., industry flood hazard data, properties at high-risk of flood identified by insurers).

Objective 2: Survey P&C insurance companies with Canadian operations to assess their level of interest to share their flood risk insights and company data with government agencies.

Objective 3: Evaluate whether a data platform that integrates public and private flood risk data is of interest to municipal officials and insurance representatives to inform FRM efforts.

The second study explored the idea of a data platform that could facilitate data-transfer and collaboration between insurers and Canadian municipal officials. This study leveraged the principles of effective flood risk governance outlined by Alexander et al. (2016) to conceptualize a set of capabilities a data platform could provide to foster cross-sector collaboration. For example, to *increase capacity to recover from a flood*, the data platform would provide insurers access to data on municipal flood protection infrastructure, which international literature suggests could increase the availability and affordability of flood insurance (Bevere & Finucane, 2022; OECD, 2016). Officials from 59 municipalities and representatives from seven P&C companies responded to a survey that assessed their level of interest in the data platform, its proposed capabilities, and its intended objectives (***Objectives 1 and 2***). Municipal officials confirmed they largely do not have access to data or information about flood insurance (6/59; 10%), offering evidence of the fragmented nature of Canadian flood risk governance. Actors in both sectors did not express strong opposition to sharing some of their data with the other sector. Regarding the data platform, municipal officials were interested in seeing high-risk areas that insurance companies had identified (78%) for informing risk mitigation investments and floodplain regulations and zoning (66%)(***RQ1 and 2; Objective 3***). Insurers were interested in (1)

receiving updates about new flood model data created by governments (e.g., LiDAR topography data)(71%), and (2) annual updates on where flood protection upgrades have been made (57%), which they indicated could increase confidence in their company's flood risk assessments (71%) and promote fair competition between insurance companies (71%), and change where their company offers flood insurance (e.g., high-risk postal codes)(57%) (*RQ1 and 2; Objective 3*). Insurers were more muted about the data platform's potential influence on increasing or decreasing flood premiums, but the study concluded the conceptual data platform should be explored further given participants' interests.

5.1.3 Study #3: Evaluating a public-private data-sharing platform for improving flood insurance availability and affordability (*Chapter 4*)

Study #3 research questions (RQ): RQ1: Does the fragmented governance approach to flood risk management create barriers for alleviating problems of flood insurance availability and affordability in Canada? RQ2: Is a data platform an appropriate, feasible and effective tool to improve and sustain the availability and affordability of flood insurance in Canada? RQ3: Are there more effective alternatives than a data platform to improve the availability and affordability of flood insurance in Canada?

Objective 1: Develop a data platform prototype that captures the interests of municipal officials and insurance companies reported in *Study #2*.

Objective 2: Interview municipal officials and insurance representatives to evaluate the data platform and assess whether they would share data with the other sector via this platform and identify foreseeable effects of cross-sector data-sharing.

Objective 3: Analyze the interview data and determine if a data platform is an appropriate, feasible and effective tool to improve the availability and affordability of flood insurance in Canada.

The third study further explored the viability of the data platform by presenting a prototype to stakeholders, who then evaluated it during interviews. The study presented the Resilience Bridge Platform (“RB Platform”)—a tool for municipal officials and insurers to share data with the objective of reducing the number of high-risk “uninsurable” properties in Canada (*Objective 1*). The RB Platform, it was proposed, would make government data accessible to insurers to refine their property flood risk assessments, thereby potentially correcting cases where risks may have been overestimated due to model assumptions and uncertainties. The RB Platform would also make insurer data on the location of high-risk properties available to municipal officials, which would inform their flood risk reduction efforts.

Participants recognized the RB Platform could act as a “missing link” between municipal officials and insurers and acknowledged it could make insurers more aware of flood protection infrastructure that is currently difficult to track (*RQ1; Objective 2*). However, the interview results ultimately signalled that the RB Platform would be unlikely to achieve its objective, for several reasons (*RQ2; Objective 3*). First, new data access would not suffice for insurers to adjust premiums and underwriting processes. Industry representatives indicated that municipal flood protection information would not spur them to change premium pricing unless the data could be validated over time for consistency and reliability and proven through a reduction in claims. Second, municipal interviewees reported that receiving data about the location of insurer-designated “high risk” properties would be insufficient to impel changes in risk reduction efforts without a deeper understanding of the factors leading to this risk categorization. The study

findings made a compelling case for a multi-level government approach to data collection on flood hazards and resilience data, rather than a municipal-insurer data-sharing partnership. Furthermore, the study concluded that a formal process of appeal is needed for citizens to redress disputes with their insurer, which would also provide documentation for governments to assess what is needed to transition a household from being “uninsurable” to “insurable” (*RQ3*).

5.2 Contributions to flood risk governance literature

This dissertation makes two key contributions to flood risk governance literature. The first pertains to methodologies for evaluating the effectiveness of flood risk governance for detecting “entry-points” for improvement, and the second is a philosophical contribution concerning flood risk governance fragmentation and integration.

The process of identifying “entry-points” for improving flood risk governance has been dominated largely by qualitative studies, such as desk analysis and interviews (e.g., Alexander et al., 2016b; Hegger, Driessen, Wiering, et al., 2016). This dissertation demonstrates the contribution that geographers—particularly digital geographers—can make to flood risk governance evaluation. Geography is a multi-disciplinary field of inquiry that leverages physical and social sciences and increasingly harnesses digital technologies to find solutions to social problems. This dissertation leveraged geospatial technologies to visually demonstrate the impacts of flood risk governance fragmentation, such as through the comparative analysis of flood hazard data used by insurers and data used by governments (*Chapter 2*). In *Chapter 4*, geospatial technologies were leveraged once again to operationalize a conceptual governance integration tool, assist stakeholders in understanding the idea and prompt feedback on the tool’s perceived effectiveness in overcoming flood insurability problems. This dissertation demonstrated the role of digital geographers in creating tools that foster flood risk governance

integration, as has been recommended by scholars such as McClymont et al. (2019) and Morrison et al. (2018).

More broadly, this dissertation makes a contribution concerning flood risk governance fragmentation and integration. It has been observed that “fragmentation within FRM systems, in terms of the distribution of responsibilities between actors and governing rules...can prove detrimental to the effectiveness of FRM” (Gilissen et al., 2015, p. 12). In Canada, it is evident that the lack of consistent government commitment to flood hazard and resilience data collection perpetuates duplicative, parallel and siloed efforts for understanding flood risk. This patchwork of data silos is not only inefficient, but it also prevents actors from understanding and appreciating changes in flood risk and FRM over time. Hegger et al. (2016) argue that “bridging mechanisms may be an important way to establish links between [FRM] strategies” (p. 10). However, this dissertation demonstrated the complexities of establishing such “bridging mechanisms” because it is a challenge to discern *how* to do so in a way that is context-appropriate and effective at achieving its intended objectives.

As demonstrated in this dissertation, identifying and evaluating “entry-points” for integrating public and private sector FRM efforts is laborious and might even distract from more significant problems with FRM. Although it is important to explore potential FRM linkages between the P&C insurance industry and governments, addressing the most important problems with FRM do not require industry involvement. CUPE (2019) observes, for example, that municipalities “need an injection of over \$50 billion to renew [municipally-controlled water and wastewater] infrastructure in poor or very poor condition” (CUPE, 2019). Moreover, all levels of government could collaborate in a concerted effort to prevent irresponsible development on floodplains, using tools such as mapping, tracking, economic incentives and regulatory

enforcement. Resolving these two problems—merely two examples among many—does not require industry involvement, but rather a concerted and integrated *governmental* approach to FRM.

5.3 Practical contributions

This dissertation found that establishing a municipal-insurer data-sharing partnership is not justified to improve flood insurance availability and affordability in Canada. Nevertheless, the process of evaluating the effects of fragmentation in Canada’s governance approach to FRM revealed two alternative strategies:

1. A coordinated *governmental* approach to flood hazard and resilience data collection
2. A formal process of appeal

Insurers with operations in Canada perceive they have better information about flood risk than government agencies. If this perception is factual, it raises two questions for government agencies. If it is true, why is this information not relied upon for government FRM decision-making (e.g., land use and infrastructure)? If it is false, who is responsible for correcting insurers property flood risk assessments? On one end, if insurers indeed have more accurate flood risk information than government agencies, government agencies should be factoring this information in flood damage prevention because the public is who would be impacted by the mismanagement of foreseeable flood risk. On the other end, if insurers are incorrect, the public is paying a premium for a risk they do not possess.

Although there are some initiatives underway to fill national data gaps (e.g., 2021-2024 Flood Hazard Identification Program) there is a need for an ongoing intergovernmental commitment to maintain a national flood hazard and resilience database in the long-term. Such a

database would not only increase efficiency by aligning duplicative flood hazard mapping efforts, but would also increase the legitimacy of floodplain development restrictions, build support for investments in flood protection infrastructure, clarify the boundaries of areas that are protected areas versus unprotected from flood damages, create opportunities for research based on a commonly and scientifically accepted view of flood risk, and assist a process of inquiry about insurers' interpretations of flood risk.

One of the most striking findings of this dissertation is that both municipal officials and insurers reported residents are seeking ways to access flood insurance coverage or receive a discounted flood premium. Municipal officials indicated that residents had approached them for financial assistance to install property-level flood protection measures in hopes to gain access to flood insurance coverage. Insurers indicated that residents were approaching local agents with information on flood protections in their neighborhood that they perceived should warrant a flood premium discount.

Given that municipalities do not know the factors insurers use to classify a property as "high risk", the definition of "high risk" varies across insurance companies, and some residents are already seeking ways to become more insurable, a process of appeal could be what is needed. Such an appeal process would enable a resident to file a complaint against an insurer if they believe they are unjustly categorized as high-risk. The appeal process could lead to reconsideration by the insurer, while also generating information for governments to better understand the factors that lead to high-risk categorization. The research for this dissertation revealed that insurers might be missing information about local FRM investments, so an appeal body could formalize a process by which property owners can communicate additional pertinent information to an insurer. This process would likely be needed in circumstances when the

property owner has already “shopped around” for flood coverage with different companies and has attempted to work on a resolution one-on-one with their insurer.

5.4 Conclusions and future research

International bodies such as the United Nations are “promoting a unique multi-stakeholder, whole-of-society and inclusive approach to reducing risks and vulnerabilities to disasters” (United Nations, 2019). Although there is a role to play in FRM for non-governmental institutions and civil society, governments have the primary legitimacy and capacity to spearhead most elements of FRM. To improve the effectiveness of flood risk governance in Canada, a long-term, intergovernmental commitment is needed to collect and maintain flood risk and resilience data. A national database could buttress the position of government agencies across all levels as both leaders in FRM and reliable partners for insurers. Continuing investment in flood damage prevention and effective communication of progress in FRM could increase confidence in flood insurance markets, particularly as the global re/insurance industry seeks avenues to reduce their exposure to growing catastrophe risks (Moody’s, 2023).

There are at least three areas of future research that emerge from the findings of this dissertation:

1. **The experience of the public.** A useful next step to this research would be to seek those residents who have advocated for themselves to (re-)gain access to flood insurance coverage or better premiums, in order to understand their experience. Were they successful in acquiring flood insurance coverage? What did that process entail? Which types of information and/or actions were needed for the resident to build a case, negotiate access to flood insurance or obtain a better rate?

- 2. Defining “reliability” for flood defence data.** Insurers argue they need reliable data to assess, quantify and price flood risk. One insurer suggested they would need access to a polygon dataset with a metric that signifies the level of protection. They later added that they would need “standardized [engineering] grading” so “we can get everyone on the same page in terms of what we rate as a quality of defence” and a “committee of engineers to mark that defense” (Insurer 7 transcript). What this might mean for different types of FRM infrastructure, such as for defences for pluvial, riverine and coastal flooding, is to be determined.
- 3. Changing nature of high-risk “uninsurable” properties.** One of the questions that remains unanswered is which factors might lead to a property being re-classified from a high to a lower risk category? Since insurers re-evaluate property-level flood risk as new information emerges and as flood models are updated, then what information might be required to transition properties from an “uninsurable” to an “insurable” category?

References

- Alberta Government. (2021a). *Disaster Recovery Programs*. Alberta Government.
<https://www.alberta.ca/disaster-recovery-programs.aspx>
- Alberta Government. (2021b). *Insurable disasters*. <https://www.alberta.ca/insurable-disasters.aspx>
- Alberta WaterPortal Society. (2014). *How Are Flood Maps Created In Alberta?* Alberta WaterPortal Society. <https://albertawater.com/how-are-flood-maps-created-in-alberta>
- Alexander, M., Priest, S., & Mees, H. (2016a). A framework for evaluating flood risk governance. *Environmental Science & Policy*, 64, 38–47.
<https://doi.org/10.1016/j.envsci.2016.06.004>
- Alexander, M., Priest, S., & Mees, H. (2016b). A framework for evaluating flood risk governance. *Environmental Science & Policy*, 64, 38–47.
<https://doi.org/10.1016/j.envsci.2016.06.004>
- Al-Shibeeb, D. (2022, June 7). Up to 10% of Canadian homes are uninsurable for flooding: Here's what you need to know. *Financial Post*. <https://financialpost.com/moneywise-pro/up-to-10-of-canadian-homes-are-uninsurable-for-flooding-heres-what-you-need-to-know>
- Ambiental. (2023). *Global Flood Insurance Analytics*. Ambiental Risk.
<https://www.ambientalrisk.com/global-flood-insurance-analytics/>
- Andersen, C. F., & American Society of Civil Engineers (Eds.). (2007). *The New Orleans hurricane protection system: What went wrong and why: a report*. ASCE.
- Association of British Insurers. (2008). *Revised Statement of Principles on the Provision of Flood Insurance*. Association of British Insurers.

<https://www.abi.org.uk/globalassets/sitecore/files/documents/publications/public/migrate-d/flooding/statement-of-principles-england.pdf>

Atreya, A., Hanger, S., Kunreuther, H., Linnerooth-Bayer, J., & Michel-Kerjan, E. (2015). A *Comparison of Residential Flood Insurance Markets in 25 Countries* (p. 44). University of Pennsylvania. https://riskcenter.wharton.upenn.edu/wp-content/uploads/2020/03/WP2015_FloodInsurancePrograms-25Countries_2015-06-28.pdf

Bernhofen, M. V., Cooper, S., Trigg, M., Mdee, A., Carr, A., Bhave, A., Solano-Correa, Y. T., Pencue-Fierro, E. L., Teferi, E., Haile, A. T., Yusop, Z., Alias, N. E., Sa'adi, Z., Bin Ramzan, M. A., Dhanya, C. T., & Shukla, P. (2022). The Role of Global Data Sets for Riverine Flood Risk Management at National Scales. *Water Resources Research*, 58(4), e2021WR031555. <https://doi.org/10.1029/2021WR031555>

Bevere, L., & Finucane, J. (2022). *Economic Insights—Flood: New risk-based pricing capabilities, new opportunities to close protection gaps*. Swiss Re Institute. <https://www.swissre.com/dam/jcr:e152fdcf-ae16-4225-8705-b5948f4a47cc/2022-september-sri-economic-insights-flood-risk.pdf>

Bevere, L., & Remondi, F. (2022). *Natural Catastrophes in 2021: The floodgates are open* (p. 36). Swiss Re Management Ltd. <https://www.swissre.com/dam/jcr:326182d5-d433-46b1-af36-06f2aedd9d9a/swiss-re-institute-sigma-natcat-2022-en.pdf>

Botzen, W., Bergh, J., & Bouwer, L. (2010). Climate change and increased risk for the insurance sector: A global perspective and an assessment for the Netherlands. *Natural Hazards*, 52(3), 577–598. <https://doi.org/10.1007/s11069-009-9404-1>

- Botzen, W. J. W., & van den Bergh, J. C. J. M. (2008). Insurance against climate change and flooding in the Netherlands: Present, future, and comparison with other countries. *Risk Analysis: An Official Publication of the Society for Risk Analysis*, 28(2), 413–426. <https://doi.org/10.1111/j.1539-6924.2008.01035.x>
- Bouwer, L. M. (2013). Projections of Future Extreme Weather Losses Under Changes in Climate and Exposure: Projections of Future Extreme Weather Losses. *Risk Analysis*, 33(5), 915–930. <https://doi.org/10.1111/j.1539-6924.2012.01880.x>
- Bruce, J. P. (1976). The National Flood Damage Reduction Program. *Canadian Water Resources Journal*, 1(1), 5–13.
- Calamai, L., & Minano, A. (2017). Emerging trends and future pathways: A commentary on the present state and future of residential flood insurance in Canada. *Canadian Water Resources Journal*, 42(4), 307–314.
- Canada, I. (2018, September 6). *Infrastructure Canada - Disaster Mitigation and Adaptation Fund: Overview*. <https://www.infrastructure.gc.ca/dmaf-faac/index-eng.html>
- Canada, P. S. (2018, December 21). *National Disaster Mitigation Program (NDMP)*. <https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgn/ndmp/index-en.aspx>
- Canada, P. S. (2020, November 23). *Government of Canada Creates Task Force on Flood Insurance and Relocation* [News releases]. <https://www.canada.ca/en/public-safety-canada/news/2020/11/government-of-canada-creates-task-force-on-flood-insurance-and-relocation.html>
- CatIQ. (2020). *CatIQ 2020 Catalogue* (p. 12). Catastrophe Indices and Quantification Inc. (CatIQ). <https://www.catiq.com/Portals/10/Docs/CatIQ-2020-Catalogue.pdf>

- Chakraborty, L. (2019). *Assessing Social Vulnerability to Flood Hazards in Canada's Three Largest Census Metropolitan Areas*.
- Chandler, J. (2022). 'The most costly natural hazard': How experts predict where flooding will happen in Ontario. TVO Today. <https://www.tvo.org/article/the-most-costly-natural-hazard-how-experts-predict-where-flooding-will-happen-in-ontario>
- City of Calgary. (2020a). *Calgary River Flood Story*. City of Calgary. <https://maps.calgary.ca/riverflooding/>
- City of Calgary. (2020b). *Flood Maps*. City of Calgary. <https://www.calgary.ca/PDA/pd/Pages/Calgary-Land-Use-by-law-1P2007/Floodway-flood-fringe-maps.aspx>
- City of Calgary. (2021a). *Division 3: Floodway, Flood Fringe and Overland Flow*. City of Calgary - Land Use By-Law. http://lub.calgary.ca/Part3/Division_3_Floodway%2C_Flood_Fringe_and_Overland_Flow.htm
- City of Calgary. (2021b). *Ward Profiles*. City of Calgary. </csps/cns/research-and-strategy/community-profiles/ward-profiles.html>
- City of Toronto. (2021). *Ward Profiles* (Toronto, Ontario, Canada). City of Toronto; City of Toronto. <https://www.toronto.ca/city-government/data-research-maps/neighbourhoods-communities/ward-profiles/>
- Climate-ADAPT. (2021). *Use of insurance loss data by local authorities in Norway*. <https://climate-adapt.eea.europa.eu/metadata/case-studies/use-of-insurance-loss-data-by-local-authorities-in-norway>

- Costa, J. E. (1978). The dilemma of flood control in the United States. *Environmental Management*, 2(4), 313–322. <https://doi.org/10.1007/BF01866671>
- CRED, & UNDRR. (2020). *Human Cost of Disasters: An overview of the last 20 years 2000-2019* (p. 17). Centre for Research on the Epidemiology of Disasters (CRED), UN Office for Disaster Risk Reduction (UNDRR).
- CRED, & UNISDR. (2016). *Poverty and Death: Disaster Mortality (1996-2015)* (p. 22). Centre for Research on the Epidemiology of Disasters.
https://www.preventionweb.net/files/50589_creddisastermortalityallfinalpdf.pdf
- CUPE. (2019, May 27). *Public infrastructure builds a sustainable, equitable future*. Canadian Union of Public Employees (CUPE). <https://cupe.ca/public-infrastructure-builds-sustainable-equitable-future>
- CWN. (2020). *Framing the Canadian Centre for Climate Information and Analytics to advance municipal flood management*. <https://cwn-rce.ca/wp-content/uploads/CWN-Oct-2020-Framing-the-C3IA-to-Advance-Municipal-Flood-Management.pdf>
- CWN, & IBC. (2019). *Improving Flood Risk Evaluation Through Cross-Sector Sharing of Richer Data* (p. 10). Canadian Water Network (CWN). <http://cwn-rce.ca/project/improving-flood-risk-evaluation-through-cross-sector-sharing-of-richer-data/>
- de Moel, H., Jongman, B., Kreibich, H., Merz, B., Penning-Rowsell, E., & Ward, P. J. (2015). Flood risk assessments at different spatial scales. *Mitigation and Adaptation Strategies for Global Change*, 20(6), 865–890. <https://doi.org/10.1007/s11027-015-9654-z>

- Der Sarkissian, R., Al Sayah, M. J., Abdallah, C., Zaninetti, J.-M., & Nedjai, R. (2022). Land Use Planning to Reduce Flood Risk: Opportunities, Challenges and Uncertainties in Developing Countries. *Sensors*, 22(18), Article 18. <https://doi.org/10.3390/s22186957>
- Driessen, P., Hegger, D., Kundzewicz, Z., van Rijswick, H., Crabbé, A., Larrue, C., Matczak, P., Pettersson, M., Priest, S., Suykens, C., Raadgever, G., & Wiering, M. (2018). Governance Strategies for Improving Flood Resilience in the Face of Climate Change. *Water*, 10(11), 1595. <https://doi.org/10.3390/w10111595>
- Dufty, N., Dyer, A., & Golnaraghi, M. (2020). *Flood Risk Management in Australia: Building flood resilience in a changing climate* (p. 58). The Geneva Association. https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf_public/frm_australia_web.pdf
- EMO Nova Scotia. (2021). *Disaster Financial Assistance Fact Sheet*. <https://beta.novascotia.ca/sites/default/files/documents/1-1401/disaster-financial-assistance-fact-sheet-en.pdf>
- FCM. (2022). *National Adaptation Strategy: Recommendations from the Federation of Canadian Municipalities* (p. 30). Federation of Canadian Municipalities (FCM). <https://data.fcm.ca/documents/resources/reports/FCM-National-Adaptation-Strategy-Report.pdf>
- FEMA. (2022). *Flood Insurance*. Federal Emergency Management Agency (FEMA). <https://www.fema.gov/flood-insurance>
- FEMA. (2023). *Community Rating System*. FEMA.Gov. <https://www.fema.gov/floodplain-management/community-rating-system>

- Floodplain Management Australia. (2015). *Local Government and Insurance Sharing Flood Risk Information*. Floodplain Management Australia.
https://www.floods.org.au/client_images/1787678.pdf
- FMA, I. (2022). *Local Government and Insurance Insurer Flood Data Requirements* (p. 2). Floodplain Management Association (FMA), Insurance Council of Australia (ICA).
https://www.floods.asn.au/client_images/1787682.pdf
- Gallichan-Lowe, S. (2018). *How the 2013 Calgary flood forced an insurance industry rethink: 'It changed everything.'* Global News. <https://globalnews.ca/news/4254206/2013-calgary-flood-insurance-changes/>
- Gilissen, H. K., Abawua, M., Beyers, J., Chmielewski, P., Schellenberger, T., & Suykens, C. (2016). Bridges over Troubled Waters: An Interdisciplinary Framework for Evaluating the Interconnectedness within Fragmented Flood Risk Management Systems. *Journal of Water Law*, 25(1), 12–26.
- Gilissen, H. K., Alexander, M., Beyers, J.-C., Chmielewski, P., Matczak, P., Schellenberger, T., & Suykens, C. (2015). Bridges Over Troubled Waters: An Interdisciplinary Framework for Evaluating the Interconnectedness Within Fragmented Domestic Flood Risk Management Systems. *The Journal of Water Law*, 25.
- GOC. (2023). *Budget 2023* (p. 270). Government of Canada (GOC).
<https://www.budget.canada.ca/2023/pdf/budget-2023-en.pdf>
- Golnaraghi, M., Thistlethwaite, J., Henstra, D., & Stewart, C. (2020a). *Flood Risk Management in Canada* (p. 66). The Geneva Association.
https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf_public/frm_canada_web.pdf

Golnaraghi, M., Thistlethwaite, J., Henstra, D., & Stewart, C. (2020b). *Flood Risk Management in Canada: Building flood resilience in a changing climate* (p. 66). The Geneva Association.

Government of Alberta. (2013). *Alberta to support relocation from floodways*. Government of Alberta. <https://www.alberta.ca/news.aspx>

Government of Canada, S. C. (2017, February 8). *Census in Brief: Municipalities in Canada with the largest and fastest-growing populations between 2011 and 2016*. <https://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016001/98-200-x2016001-eng.cfm>

Government of Canada, S. C. (2019, November 12). *Table 4.2 CSD type*. <https://www150.statcan.gc.ca/n1/pub/92-162-g/2019001/tbl/tbl4.2-eng.htm>

Government of Canada, S. C. (2022a, February 9). *Population and dwelling counts: Canada and census subdivisions (municipalities)*. <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810000201>

Government of Canada, S. C. (2022b, February 9). *Population and dwelling counts: Canada, provinces and territories*. <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810000101>

Government of Canada, S. C. (2022c, February 9). *The Daily—Canada's large urban centres continue to grow and spread*. <https://www150.statcan.gc.ca/n1/daily-quotidien/220209/dq220209b-eng.htm>

Government of Canada, S. C. (2022d, June 1). *Census Subdivision Boundary File*. <https://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-s-eng.cfm?year=22>

Government of Ontario. (2020). *Apply for disaster recovery assistance*.

<https://www.ontario.ca/page/apply-disaster-recovery-assistance>

Halifax Regional Municipality. (2020). *Sackville Rivers Floodplains*. Halifax Regional Municipality.

<http://www.arcgis.com/apps/webappviewer/index.html?id=54adf80df5d94459a8ea08554997fa07>

Hampton, S., & Curtis, J. (2022). A bridge over troubled water? Flood insurance and the governance of climate change adaptation. *Geoforum*, *136*, 80–91.

<https://doi.org/10.1016/j.geoforum.2022.08.008>

Haney, T. J. (2017). *Rising Waters, Difficult Decisions: Findings and Recommendations from the Calgary Flood Project*. Centre for Community Disaster Research.

Hanger, S., Linnerooth-Bayer, J., Surminski, S., Nenciu-Posner, C., Lorant, A., Ionescu, R., & Patt, A. (2018). Insurance, Public Assistance, and Household Flood Risk Reduction: A Comparative Study of Austria, England, and Romania: Insurance, Public Assistance, and Household Flood Risk Reduction. *Risk Analysis*, *38*(4), 680–693.

<https://doi.org/10.1111/risa.12881>

Hegger, D., Driessen, P., & Bakker, M. (2016). *A view on more resilient flood risk governance: Key conclusions of the STAR-FLOOD project*.

<http://www.starflood.eu/documents/2016/03/d6-4-final-report-webversion.pdf>

Hegger, D., Driessen, P., & Bakker, M. (2018). Researching Flood Risk Governance in Europe. In T. Raadgever & D. Hegger (Eds.), *Flood risk management strategies and governance* (pp. 3–23). Springer Berlin Heidelberg.

- Hegger, D., Driessen, P., Wiering, M., van Rijswijk, H., Kundzewicz, Z., Matczak, P., Crabbé, A., Raadgever, G., Bakker, M., Priest, S., Larrue, C., & Ek, K. (2016). Toward more flood resilience: Is a diversification of flood risk management strategies the way forward? *Ecology and Society*, *21*(4). <https://doi.org/10.5751/ES-08854-210452>
- Henstra, D., Minano, A., & Thistlethwaite, J. (2019). Communicating disaster risk? An evaluation of the availability and quality of flood maps. *Natural Hazards and Earth System Sciences*, *19*(1), 313–323. <https://doi.org/10.5194/nhess-19-313-2019>
- Hodgson, G. (2022). *Under Water: Where is the flood insurance coverage?* C.D. Howe Institute. <https://www.cdhowe.org/expert-op-eds/under-water-where-flood-insurance-coverage-globe-and-mail-op-ed>
- Holsboer, J. H. (1995). Insurability and Uninsurability: An Introduction. *The Geneva Papers on Risk and Insurance - Issues and Practice*, *20*(4), 407–413. <https://doi.org/10.1057/gpp.1995.33>
- Hooijer, A., & Vernimmen, R. (2021). Global LiDAR land elevation data reveal greatest sea-level rise vulnerability in the tropics. *Nature Communications*, *12*(1), Article 1. <https://doi.org/10.1038/s41467-021-23810-9>
- HRM. (2016). *2016 Population of HRM by Districts*. Halifax Regional Municipality (HRM). <https://www.halifax.ca/sites/default/files/documents/city-hall/elections/2016PopulationofHRMbyDistricts.pdf>
- HRM. (2020). *Land Use By-Law Bedford*. Halifax Regional Municipality (HRM). <https://www.halifax.ca/sites/default/files/documents/business/planning-development/applications/Bedford-LUB-Eff-20Nov07-Case21162-TOCLinked.pdf>

- HRM. (2021). *Sackville Floodplains*. Halifax Regional Municipality (HRM).
<https://www.halifax.ca/about-halifax/regional-community-planning/sackville-floodplains>
- IBC. (2019). *Options for Managing Flood Costs of Canada's Highest Risk Residential Properties* (p. 56). Insurance Bureau of Canada (IBC).
<http://www.ibc.ca/on/resources/studies/options-for-managing-flood-costs-of-canada%E2%80%99s-highest-risk-residential-properties>
- ICA. (2023). *Flood insurance explained*. Insurance Council of Australia (ICA).
<https://insurancecouncil.com.au/resource/flood-insurance-explained/>
- Infrastructure Canada. (2018, May 17). *Backgrounder: Disaster Mitigation and Adaptation Fund*. Government of Canada. <https://www.canada.ca/en/office-infrastructure/news/2018/05/backgrounder-disaster-mitigation-and-adaptation-fund.html>
- Insurance Council of Australia. (2011). *Local Government and Insurance Flood Insurance Pricing*.
- Insurance Council of Australia. (2021). *Affordability Projects*.
<https://www.insurancecouncil.com.au/affordability>
- Insurance Council of Australia & Floodplain Management Australia. (2019). *Local Government and Insurance Sharing Flood Risk Information*. Floodplain Management Australia.
http://www.floods.org.au/client_images/1787678.pdf
- IPCC. (2014). *Climate Change 2014 Synthesis Report: Summary for Policymakers* (p. 32). Intergovernmental Panel on Climate Change (IPCC).
https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

- IPCC. (2022a). *Summary for Policymakers* (pp. 3–33). Cambridge University Press.
https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf
- IPCC. (2022b). *Technical Summary* (pp. 37–118). Cambridge University Press.
https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_TechnicalSummary.pdf
- JBA. (2018). *JBA Global 30m Flood Maps*.
<https://www.nasdaq.com/docs/JBA%20global%20flood%20map%202018.pdf>
- JBA. (2020). *JBA Canada 30m Flood Data Executive Briefing*. JBA Risk Management (JBA).
<https://www.nasdaq.com/docs/2020/04/26/JBA%20Canada%2030m%20Flood%20Data%20Executive%20Briefing.pdf>
- Jha, A., Bloch, R., & Lamond, J. (2012). *Cities and flooding: A guide to integrated urban flood risk management for the 21st century*. World Bank.
- Jongman, B., Ward, P. J., & Aerts, J. C. J. H. (2012). Global exposure to river and coastal flooding: Long term trends and changes. *Global Environmental Change*, 22(4), 823–835.
<https://doi.org/10.1016/j.gloenvcha.2012.07.004>
- Kousky, C., & Golnaraghi, M. (2020). *Flood Risk Management in the United States: Building flood resilience in a changing climate* (p. 56). The Geneva Association.
<https://www.genevaassociation.org/sites/default/files/flood-risk-management-usa.pdf>
- Kovacs, P., & Kunreuther, H. (2001). *Managing Catastrophic Risk: Lessons from Canada*. 29.
<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.196.4754&rep=rep1&type=pdf>
- Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L. M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G. R.,

- Kron, W., Benito, G., Honda, Y., Takahashi, K., & Sherstyukov, B. (2014). Flood risk and climate change: Global and regional perspectives. *Hydrological Sciences Journal*, 59(1), 1–28. <https://doi.org/10.1080/02626667.2013.857411>
- Kunreuther, H. (1996). Mitigating disaster losses through insurance. *Journal of Risk and Uncertainty*, 12(2–3), 171–187. <https://doi.org/10.1007/BF00055792>
- Kutija, V., Bertsch, R., Glenis, V., Alderson, D., Parkin, G., Walsh, C., Robinson, J., & Kilsby, C. (2014). Model Validation Using Crowd-Sourced Data From A Large Pluvial Flood. *International Conference on Hydroinformatics*.
https://academicworks.cuny.edu/cc_conf_hic/415
- Lamond, J. E., Proverbs, D. G., & Hammond, F. N. (2009). Accessibility of flood risk insurance in the UK: Confusion, competition and complacency. *Journal of Risk Research*, 12(6), 825–841. <https://doi.org/10.1080/13669870902768614>
- Lamond, J., & Penning-Rowsell, E. (2014). The robustness of flood insurance regimes given changing risk resulting from climate change. *Climate Risk Management*, 2, 1–10.
<https://doi.org/10.1016/j.crm.2014.03.001>
- LGNZ. (2022). *Sensible solutions to flood risk must be supported*.
<https://www.lgnz.co.nz/sensible-solutions-to-flood-risk-must-be-supported-lgnz>
- Mason. (2011). *The History of Flood Insurance in Australia*. 12.
- Mcclearn, M. (2019, April 26). *Poor flood-risk maps, or none at all, are keeping Canadian communities in flood-prone areas*. <https://www.theglobeandmail.com/canada/article-poor-flood-risk-maps-or-none-at-all-are-keeping-canadian-communities/>

- McClymont, K., Morrison, D., Beevers, L., & Carmen, E. (2019). Flood resilience: A systematic review. *Journal of Environmental Planning and Management*, 0(0), 1–26.
<https://doi.org/10.1080/09640568.2019.1641474>
- Meckbach, G. (2016, February 2). *New IBC flood model shows 1.8 million Canadian households at “very high risk.”* <http://www.canadianunderwriter.ca/insurance/new-ibc-flood-model-shows-1-8-million-canadian-households-at-very-high-risk-1004006457/>
- Meckbach, G. (2017). Flood Money. *Canadian Underwriter*.
<https://www.canadianunderwriter.ca/features/flood-money/>
- Minano, A., Thistlethwaite, J., Henstra, D., & Scott, D. (2021). Governance of flood risk data: A comparative analysis of government and insurance geospatial data for identifying properties at risk of flood. *Computers, Environment and Urban Systems*, 88(1), 101636.
<https://doi.org/10.1016/j.compenvurbsys.2021.101636>
- Minano A., Thistlethwaite, J., Henstra, D. (submitted). Conceptualizing and evaluating the role of a data platform for strengthening flood risk governance. *Journal of Disaster Risk Reduction*.
- Minerva Intelligence. (2020). *Minerva Intelligence, in Partnership with Ebbwater Consulting, Announces Commercial Contract with Natural Resources Canada*. Minerva Intelligence.
<https://minervaintelligence.com/natural-resources-canada/>
- MongoDB. (2022). *What Is A Data Platform?* MongoDB. <https://www.mongodb.com/what-is-a-data-platform>
- Moody’s. (2023). *Reinsurers defend against rising tide of natural catastrophe losses, for now*. Moody’s. <https://www.moody.com/web/en/us/about/insights/data-stories/reinsurers-mitigate-lower-profits.html>

- Morrison, A., Westbrook, C. J., & Noble, B. F. (2018). A review of the flood risk management governance and resilience literature. *Journal of Flood Risk Management*, 11(3), 291–304. <https://doi.org/10.1111/jfr3.12315>
- Nadarajah, I. (2016). *Flood insurance in Canada*. <https://www.insuranceinstitute.ca/en/cipsociety/information-services/advantage-monthly/0316-flood-insurance>
- National Academies Press. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices*. <https://doi.org/10.17226/18309>
- National Academies Press. (2015). *Read “Affordability of National Flood Insurance Program Premiums: Report 1” at NAP.edu*. <https://doi.org/10.17226/21709>
- National Research Council Canada. (2015). NFIP Procedures for Analyzing Flood Hazard and Calculating Insurance Rates. In *Tying Flood Insurance to Flood Risk for Low-Lying Structures in the Floodplain* (p. 86). The National Academies Press. <https://doi.org/10.17226/21720>
- OECD. (2016). *Financial Management of Flood Risk*. OECD Publishing.
- Office of the Prime Minister. (2021, January 15). *Minister of Public Safety and Emergency Preparedness Supplementary Mandate Letter*. Prime Minister of Canada. <https://pm.gc.ca/en/mandate-letters/2021/01/15/minister-public-safety-and-emergency-preparedness-supplementary-mandate>
- O’Hare, P., White, I., & Connelly, A. (2016). Insurance as maladaptation: Resilience and the ‘business as usual’ paradox. *Environment and Planning C: Government and Policy*, 34(6), 1175–1193. <https://doi.org/10.1177/0263774X15602022>

- PBO. (2016). *Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements due to Weather Events*. Office of the Parliamentary Budget Officer.
- Penning-Rowsell, E. C., Priest, S., & Johnson, C. (2014). The evolution of UK flood insurance: Incremental change over six decades. *International Journal of Water Resources Development*, 30(4), 694–713.
- Petrucci, O., Aceto, L., Bianchi, C., Bigot, V., Brázdil, R., Pereira, S., Kahraman, A., Kılıç, Ö., Kotroni, V., Llasat, M. C., Llasat-Botija, M., Papagiannaki, K., Pasqua, A. A., Řehoř, J., Rossello Geli, J., Salvati, P., Vinet, F., & Zêzere, J. L. (2019). Flood Fatalities in Europe, 1980–2018: Variability, Features, and Lessons to Learn. *Water*, 11(8), 1682. <https://doi.org/10.3390/w11081682>
- Prail, S. (2016). *Municipal Risk Assessment Tool (MRAT)* (p. 6). Dillon Consulting.
- Province of Manitoba. (2023). *Red River Floodway*. Province of Manitoba. <https://www.gov.mb.ca/mit/wms/rrf/index.html>
- Province of Ontario. (2021). *O. Reg. 588/17: ASSET MANAGEMENT PLANNING FOR MUNICIPAL INFRASTRUCTURE*. Ontario.Ca. <https://www.ontario.ca/laws/view>
- PSC. (2020, November 23). *Task Force on Flood Insurance and Relocation*. Public Safety Canada (PSC). <https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/tsk-frc-fld-en.aspx>
- Public Safety Canada. (2022). *Adapting to Rising Flood Risk—An Analysis of Insurance Solutions for Canada* (p. 117). <https://www.publicsafety.gc.ca/cnt/rsrscs/pblctns/dptng-rsng-fld-rsk-2022/dptng-rsng-fld-rsk-2022-en.pdf>
- Ran, J., & Nedovic-Budic, Z. (2016). Integrating spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure. *Computers*,

Environment and Urban Systems, 57, 68–79.

<https://doi.org/10.1016/j.compenvurbsys.2016.01.008>

Renn, O., Klinke, A., & van Asselt, M. (2011). Coping with Complexity, Uncertainty and Ambiguity in Risk Governance: A Synthesis. *AMBIO*, 40(2), 231–246.

<https://doi.org/10.1007/s13280-010-0134-0>

Sandink, D. (2013). *Urban Flooding in Canada: Lot-Side Risk Reduction Through Voluntary Retrofit Programs, Code Interpretation and By-laws*. Institute for Catastrophic Loss Reduction.

Sandink, D., Kovacs, P., Oulahen, G., & McGillivray, G. (2010). *Making Flood Insurable for Canadian Homeowners: A Discussion Paper* (p. 75). Institute for Catastrophic Loss Reduction & Swiss Reinsurance Company Ltd.

Sayers, P., Yuanyuan, L., Galloway, G., Penning-Rowsell, E., Fuxin, S., Kang, W., Yiwei, C., & Le Quesne, T. (2013). *Flood Risk Management: A Strategic Approach*. UNESCO.

SFU. (2020). *Statistics: Canadian Census*. Simon Fraser University (SFU).

<https://www.lib.sfu.ca/help/research-assistance/format-type/census>

Shrubsole, D. (2013). A history of flood management strategies in Canada revisited. In E. Keskitalo, *Climate Change and Flood Risk Management* (pp. 95–120). Edward Elgar Publishing. <https://doi.org/10.4337/9781781006672.00009>

Stevens, M. R., & Hanschka, S. (2014). Municipal flood hazard mapping: The case of British Columbia, Canada. *Natural Hazards*, 73(2), 907–932. <https://doi.org/10.1007/s11069-014-1117-4>

- Surminski, S., Mehryar, S., & Golnaraghi, M. (2020). *Flood Risk Management in England: Building flood resilience in a changing climate* (p. 54). The Geneva Association.
<https://www.genevaassociation.org/sites/default/files/flood-risk-management-england.pdf>
- Surminski, S., Roezer, V., & Golnaraghi, M. (2020). *Flood Risk Management in Germany: Building flood resilience in a changing climate* (p. 48). The Geneva Association.
<https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf>
- Surminski, S. (2017a). *Fit for the future? The reform of flood insurance in Ireland: Resolving the data controversy and supporting climate adaptation*. Gratham Research Institute on Climate Change and the Environment. https://www.lse.ac.uk/gratham institute/wp-content/uploads/2017/05/Fit_for_the_Future_Surminski_May2017.pdf
- Surminski, S. (2017b). *Fit for Purpose and Fit for the Future? An Evaluation of the UK's New Flood Reinsurance Pool*. Resources for the Future.
<http://www.rff.org/files/document/file/RFF-DP-17-04.pdf>
- Surminski, S., & Eldridge, J. (2017). Flood insurance in England – an assessment of the current and newly proposed insurance scheme in the context of rising flood risk. *Journal of Flood Risk Management*, 10(4), 415–435. <https://doi.org/10.1111/jfr3.12127>
- Surminski, S., & Oramas-Dorta, D. (2014). Flood insurance schemes and climate adaptation in developing countries. *International Journal of Disaster Risk Reduction*, 7(Complete), 154–164. <https://doi.org/10.1016/j.ijdr.2013.10.005>
- Surminski, S., & Thielen, A. H. (2017). Promoting flood risk reduction: The role of insurance in Germany and England. *Earth's Future*, 5(10), 979–1001.
<https://doi.org/10.1002/2017EF000587>

- Swiss Re. (2019). *Closing the protection gap*. https://www.swissre.com/dam/jcr:61067508-f362-442c-9795-095862b2ee48/Closign_the_protection_gap.pdf
- Tesselaar, M., Botzen, W. J. W., Haer, T., Hudson, P., Tiggeloven, T., & Aerts, J. C. J. H. (2020). Regional Inequalities in Flood Insurance Affordability and Uptake under Climate Change. *Sustainability*, 12(20), Article 20. <https://doi.org/10.3390/su12208734>
- Thapa, A., Bradford, L., Strickert, G., Yu, X., Johnston, A., & Watson-Daniels, K. (2019). “Garbage in, Garbage Out” Does Not Hold True for Indigenous Community Flood Extent Modeling in the Prairie Pothole Region. *Water*, 11(12), Article 12. <https://doi.org/10.3390/w11122486>
- Thistlethwaite, J., Minano, A., Blake, J. A., Henstra, D., & Scott, D. (2018). Application of re/insurance models to estimate increases in flood risk due to climate change. *Geoenvironmental Disasters*, 5(1), 8. <https://doi.org/10.1186/s40677-018-0101-9>
- TRCA. (2014). *Living Cities Policies* (p. 204). Toronto Region Conservation Authority (TRCA). <https://drive.google.com/file/d/0BxjqkzmOuaaRYWxqSGdUaHp5UE0/view>
- TRCA. (2019). *Flood Plain Map*. Toronto and Region Conservation Authority (TRCA). <https://trca.ca/conservation/flood-risk-management/flood-plain-map-viewer/#map>
- UNISDR. (2015a). *From a Reactive to Proactive People Centered Approach to DRR* (p. 12). The United Nations Office for Disaster Risk Reduction (UNISDR). https://www.unisdr.org/files/49574_hfacelebrationreport7082015verdana.pdf
- UNISDR. (2015b). *Sendai Framework for Disaster Risk Reduction 2015-2030*. United Nations International Strategy for Disaster Reduction. http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf

- UNISDR. (2015c). *Sendai Framework for Disaster Risk Reduction 2015—2030* (p. 37). The United Nations Office for Disaster Risk Reduction (UNISDR).
https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf
- United Nations. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*. United Nations International Strategy for Disaster Reduction.
http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf
- United Nations. (2019). *UN Office for Disaster Risk Reduction (UNISDR)*. United Nations Department of Economic and Social Affairs. <https://sdgs.un.org/un-system-sdg-implementation/un-office-disaster-risk-reduction-unisdr-34594>
- Verisk. (2022). *Global Modeled Catastrophe Losses* (pp. 1–14). https://www.air-worldwide.com/siteassets/Publications/White-Papers/documents/2022_Global_Modeled_Catastrophe_Losses.pdf
- Watt, W. E. (1995). THE NATIONAL FLOOD DAMAGE REDUCTION PROGRAM: 1976 – 1995. *Canadian Water Resources Journal*, 20(4), 237–247.
<https://doi.org/10.4296/cwrj2004237>
- Wernick, A., & Olk, C. (2020). *Defining Data Intermediaries*. 17.
- WHO. (2022). *Floods*. World Health Organization (WHO). <https://www.who.int/health-topics/floods>
- Wing, O. E. J., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States. *Environmental Research Letters*, 13(3), 034023.
<https://doi.org/10.1088/1748-9326/aaac65>

- Winsemius, H. C., Aerts, J. C. J. H., van Beek, L. P. H., Bierkens, M. F. P., Bouwman, A., Jongman, B., Kwadijk, J. C. J., Ligtoet, W., Lucas, P. L., van Vuuren, D. P., & Ward, P. J. (2016). Global drivers of future river flood risk. *Nature Climate Change*, 6(4), 381–385. <https://doi.org/10.1038/nclimate2893>
- Wirth, F. N., Meurers, T., Johns, M., & Prasser, F. (2021). Privacy-preserving data sharing infrastructures for medical research: Systematization and comparison. *BMC Medical Informatics and Decision Making*, 21(1), 242. <https://doi.org/10.1186/s12911-021-01602-x>
- Yeo, S. (2003). Effects of disclosure of flood-liability on residential property values. *Australian Journal of Emergency Management*, 18(1), 35–44.

Appendix A

| Municipality | Province |
|------------------------|---------------------------------------|
| 1. Medicine Hat | Alberta |
| 2. Lethbridge | Alberta |
| 3. Brooks | Alberta |
| 4. Calgary | Alberta |
| 5. Chestermere | Alberta |
| 6. Airdrie | Alberta |
| 7. Red Deer | Alberta |
| 8. Lacombe | Alberta |
| 9. Camrose | Alberta |
| 10. Lloydminster | Alberta (part) / Saskatchewan (part) |
| 11. Wetaskiwin | Alberta |
| 12. Beaumont | Alberta |
| 13. Leduc | Alberta |
| 14. Spruce Grove | Alberta |
| 15. Fort Saskatchewan | Alberta |
| 16. Edmonton | Alberta |
| 17. St. Albert | Alberta |
| 18. Cold Lake | Alberta |
| 19. Grande Prairie | Alberta |
| 20. Steinbach | Manitoba |
| 21. Winkler | Manitoba |
| 22. Morden | Manitoba |
| 23. Brandon | Manitoba |
| 24. Portage la Prairie | Manitoba |
| 25. Winnipeg | Manitoba |
| 26. Selkirk | Manitoba |
| 27. Dauphin | Manitoba |
| 28. Flin Flon | Manitoba (part) / Saskatchewan (part) |
| 29. Thompson | Manitoba |
| 30. Saint John | New Brunswick |
| 31. Moncton | New Brunswick |
| 32. Dieppe | New Brunswick |
| 33. Miramichi | New Brunswick |
| 34. Fredericton | New Brunswick |
| 35. Edmundston | New Brunswick |
| 36. Campbellton | New Brunswick |
| 37. Bathurst | New Brunswick |
| 38. St. John's | Newfoundland and Labrador |
| 39. Mount Pearl | Newfoundland and Labrador |
| 40. Corner Brook | Newfoundland and Labrador |
| 41. Queens | Nova Scotia |
| 42. Halifax | Nova Scotia |

| | |
|----------------------|----------------------|
| 43. Cape Breton | Nova Scotia |
| 44. West Hants | Nova Scotia |
| 45. Charlottetown | Prince Edward Island |
| 46. Summerside | Prince Edward Island |
| 47. Estevan | Saskatchewan |
| 48. Weyburn | Saskatchewan |
| 49. Melville | Saskatchewan |
| 50. Regina | Saskatchewan |
| 51. Moose Jaw | Saskatchewan |
| 52. Swift Current | Saskatchewan |
| 53. Yorkton | Saskatchewan |
| 54. Saskatoon | Saskatchewan |
| 55. Warman | Saskatchewan |
| 56. Martensville | Saskatchewan |
| 57. Melfort | Saskatchewan |
| 58. Humboldt | Saskatchewan |
| 59. Prince Albert | Saskatchewan |
| 60. North Battleford | Saskatchewan |
| 61. Meadow Lake | Saskatchewan |
| 62. Fernie | British Columbia |
| 63. Cranbrook | British Columbia |
| 64. Kimberley | British Columbia |
| 65. Nelson | British Columbia |
| 66. Castlegar | British Columbia |
| 67. Trail | British Columbia |
| 68. Rossland | British Columbia |
| 69. Grand Forks | British Columbia |
| 70. Greenwood | British Columbia |
| 71. Penticton | British Columbia |
| 72. Chilliwack | British Columbia |
| 73. Abbotsford | British Columbia |
| 74. Langley | British Columbia |
| 75. Surrey | British Columbia |
| 76. White Rock | British Columbia |
| 77. Delta | British Columbia |
| 78. Richmond | British Columbia |
| 79. Vancouver | British Columbia |
| 80. Burnaby | British Columbia |
| 81. New Westminster | British Columbia |
| 82. Coquitlam | British Columbia |
| 83. Port Coquitlam | British Columbia |
| 84. Port Moody | British Columbia |
| 85. North Vancouver | British Columbia |
| 86. Pitt Meadows | British Columbia |
| 87. Maple Ridge | British Columbia |

| | |
|---------------------------|------------------|
| 88. Victoria | British Columbia |
| 89. Colwood | British Columbia |
| 90. Langford | British Columbia |
| 91. Duncan | British Columbia |
| 92. Nanaimo | British Columbia |
| 93. Parksville | British Columbia |
| 94. Port Alberni | British Columbia |
| 95. Campbell River | British Columbia |
| 96. Courtenay | British Columbia |
| 97. Powell River | British Columbia |
| 98. Merritt | British Columbia |
| 99. Kamloops | British Columbia |
| 100. Kelowna | British Columbia |
| 101. West Kelowna | British Columbia |
| 102. Vernon | British Columbia |
| 103. Armstrong | British Columbia |
| 104. Enderby | British Columbia |
| 105. Revelstoke | British Columbia |
| 106. Salmon Arm | British Columbia |
| 107. Williams Lake | British Columbia |
| 108. Quesnel | British Columbia |
| 109. Prince Rupert | British Columbia |
| 110. Terrace | British Columbia |
| 111. Prince George | British Columbia |
| 112. Dawson Creek | British Columbia |
| 113. Fort St. John | British Columbia |
| 114. Mission | British Columbia |
| 115. Cornwall | Ontario |
| 116. Clarence-Rockland | Ontario |
| 117. Ottawa | Ontario |
| 118. Brockville | Ontario |
| 119. Kingston | Ontario |
| 120. Belleville | Ontario |
| 121. Quinte West | Ontario |
| 122. Prince Edward County | Ontario |
| 123. Peterborough | Ontario |
| 124. Kawartha Lakes | Ontario |
| 125. Pickering | Ontario |
| 126. Oshawa | Ontario |
| 127. Vaughan | Ontario |
| 128. Markham | Ontario |
| 129. Richmond Hill | Ontario |
| 130. Toronto | Ontario |
| 131. Mississauga | Ontario |
| 132. Brampton | Ontario |

| | |
|-------------------------|---------|
| 133. Guelph | Ontario |
| 134. Burlington | Ontario |
| 135. Hamilton | Ontario |
| 136. Port Colborne | Ontario |
| 137. Welland | Ontario |
| 138. Thorold | Ontario |
| 139. Niagara Falls | Ontario |
| 140. St. Catharines | Ontario |
| 141. Haldimand County | Ontario |
| 142. Norfolk County | Ontario |
| 143. Brant | Ontario |
| 144. Brantford | Ontario |
| 145. Cambridge | Ontario |
| 146. Kitchener | Ontario |
| 147. Waterloo | Ontario |
| 148. Stratford | Ontario |
| 149. Woodstock | Ontario |
| 150. St. Thomas | Ontario |
| 151. Windsor | Ontario |
| 152. Sarnia | Ontario |
| 153. London | Ontario |
| 154. Owen Sound | Ontario |
| 155. Barrie | Ontario |
| 156. Orillia | Ontario |
| 157. Pembroke | Ontario |
| 158. North Bay | Ontario |
| 159. Greater Sudbury | Ontario |
| 160. Temiskaming Shores | Ontario |
| 161. Timmins | Ontario |
| 162. Elliot Lake | Ontario |
| 163. Sault Ste. Marie | Ontario |
| 164. Thunder Bay | Ontario |
| 165. Kenora | Ontario |
| 166. Dryden | Ontario |

Appendix B

1. Survey for municipal officials (Survey Instrument #1)

Q1. Has your municipality experienced the following situations in recent years? Check all that apply.

- Floods are happening more frequently in recent years
- Difficulties predicting which places will be impacted by floods
- More residents are affected by floods now than in the past
- Higher costs to repair flood-damaged property (e.g., public infrastructure, private property)
- Residents are unprepared to deal with flooding (e.g., during emergencies, recovering from a flood)
- Municipal resources are increasingly strained paying for flood damage repairs
- Resident or municipal concerns about changing local flood hazards due to climate change

Q2. Are there other flood-related impacts that your municipality has recently experienced?

Q3. Which type(s) of flooding affect your municipality? Check all that apply.

- Pluvial or urban flooding
- Fluvial or riverine flooding
- Coastal or storm surge flooding
- Other type(s) of flooding: _____
- I don't know which type of flooding specifically
- Flooding does not occur in my municipality

Q4. Relative to other municipal priorities, how important are flood-related impacts for your municipality?

- Not at all a problem
- Minor problem
- Moderate problem
- Serious problem

Q5. Over the next 5 years, do you anticipate that flooding will:
(e.g., recurring heavy rainfall)

- Become less frequent
- Occur at the same frequency
- Become more frequent
- I don't know / I'm not sure

Q6. Over the next 5 years, do you anticipate that the value of properties and assets exposed to flooding will:

(e.g., due to population growth, property value increases, economic growth in flood-prone areas)

- Decrease
- Remain the same
- Increase
- I don't know / I'm not sure

Q7. Which steps have been taken to manage flood risks in your municipality?

(e.g., actions taken to prevent and minimize property damages, ensure quick flood recovery)

Check all that apply.

- Invested in new floodplain mapping studies
- Collected new flood modelling data (e.g., LiDAR data)
- Established a minimum standard of flood protection (e.g., 100-year flood)
- Planned for flood events that exceed a minimum flood protection standard (e.g., 100-year flood)
- Changed (re-)development rules for designated floodplains
- Designated new lands as regulated floodplains
- Built flood protection infrastructure
- Implemented programs for incentivizing property-level flood risk mitigation
- Other steps: _____

Q8. Which steps is your municipality planning to take over the next 1-2 years to manage flood risks? (e.g., planned steps to prevent and minimize property damages, ensure quick flood recovery)

Check all that apply.

- Invest in new floodplain mapping studies
- Collect new flood modelling data (e.g., LiDAR data)
- Establish a minimum standard of flood protection (e.g., 100-year flood)
- Plan for flood events that exceed a minimum flood protection standard (e.g., 100-year flood)
- Change (re-)development rules for designated floodplains
- Designate new lands as regulated floodplains
- Build flood protection infrastructure
- Implement programs for incentivizing property-level flood risk mitigation
- Other steps: _____
- None planned at this time

Q9. Are the steps being taken to address flood impacts part of a plan/strategy?

- We're currently not taking steps to address flood impacts
- These steps are taken on an as-needed basis or when funding becomes available
- These steps are part of a plan, but the plan's execution is not monitored by government staff
- These steps are part of a plan, and the plan is monitored by government staff
- Other: _____

Q10. Would any of these information sources improve your municipality's flood risk management efforts?

(e.g., resources allocation, informing decisions, program development)

| | Definitely yes | Probably yes | Might or might not | Probably not | Definitely not |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| A list of insurance companies who offer flood insurance in your municipality | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Average price of flood insurance in your municipality | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Number of properties that are insured for flood in your municipality | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Insurance industry's fluvial (riverine) flood hazard maps | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Insurance industry's pluvial (urban) flood hazard maps | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Insurance industry's coastal flood hazard maps | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Neighborhoods/postal codes that the insurance industry considers to be high-risk of flood | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Neighborhoods/postal codes where residents are having difficulty finding affordable flood insurance | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Flood maps that capture future climate change | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Q11. Which of the following information sources does your municipality currently have access to?
Check all that apply.

- A list of insurance companies who offer flood insurance in your municipality
- Average price of flood insurance in your municipality
- Number of properties that are insured for flood in your municipality
- Insurance industry's fluvial (riverine) flood hazard maps
- Insurance industry's pluvial (urban) flood hazard maps
- Insurance industry's coastal flood hazard maps
- Neighborhoods/postal codes that the insurance industry considers to be high-risk of flood
- Neighborhoods/postal codes where residents are having difficulty finding affordable flood insurance
- Flood maps that capture future climate change
- None of the above

Q12. For what purpose would your municipality use the information described above?
(e.g., a list of insurance companies who offer flood insurance in your municipality, neighborhoods/postal codes where residents are having difficulty finding affordable flood insurance)

- Inform municipal flood risk mitigation investments
- Inform municipal floodplain regulations and zoning
- Inform residents about flood insurance
- Other purposes: _____

I don't know for what purpose at this time, but my municipality is interested in accessing that information

My municipality is not interested in using the information described above

Q13. What barriers has your municipality faced when implementing flood risk management initiatives? (e.g., initiatives that prevent and minimize property damages, ensure quick flood recovery)

Check all that apply.

Difficulties identifying what to do to address local flood risks

Difficulties knowing when to implement certain actions to address flood risks

Conflicting information about local flood risks

Lack of available resources to implement initiatives or changes (e.g., data, expertise, financial resources)

Lack of public support when implementing flood risk management initiatives (e.g., floodplain regulation changes)

Lack of political will to change current policies, processes and programs related to flood risk management (e.g., floodplain regulation changes)

Lack of incentives to continuously improve flood risk management (e.g., reward systems, clear goals)

Lack of support systems from upper levels of government (e.g., information, financial resources, policy direction)

No barriers experienced when implementing flood risk management initiatives

Q14. Are there other barriers that your municipality has faced when implementing flood risk management initiatives?

(e.g., prevent and minimize property damages, ensure quick flood recovery)

Q15. Which of the following data sources are accessible to your municipality?
(e.g., the data is in an open data repository, municipal database, other government databases available for use by your municipality)

Check all that apply.

- Digital topography data of your municipality (e.g., LiDAR Digital Elevation Models)
- Historical river gauge records for your municipality
- Historical rainfall records for your municipality
- Historical tidal gauge records for your municipality
- Places in your municipality where flooding has occurred in the past (e.g., spatial extent of historical floods)
- Places that are regulated/designated floodplains in your municipality (e.g., spatial extent of regulatory flood)
- Places that are protected from flooding in your municipality (e.g., due to levees)
- Properties that are flood-proofed because of municipal floodplain regulations (e.g., properties with raised foundations)
- Properties that have been part of municipal flood-proofing programs (e.g., sump pump subsidy programs)
- Other related data: _____
- None of the above

Q16. Which of the following data sources would your municipality be willing to share with the insurance industry to inform their flood risk analyses? (e.g., calibrating flood models, assessing property-level flood risk, calculating flood insurance premiums)

Check all that apply.

- Topography data of your municipality (e.g., LiDAR Digital Elevation Models)
- Historical river gauge records for your municipality
- Historical rainfall records for your municipality
- Historical tidal gauge records for your municipality
- Places in your municipality where flooding has occurred in the past (e.g., spatial extent of historical floods)
- Places that are regulated/designated floodplains in your municipality (e.g., spatial extent of regulatory flood)
- Places that are protected from flooding in your municipality (e.g., due to levees)
- Properties that are flood-proofed because of municipal floodplain regulations (e.g., properties with raised foundations)
- Properties that have been part of municipal flood-proofing programs (e.g., sump pump subsidy programs)
- Other related data: _____
- None of the above

Q17. Would your municipality be interested in these **functionalities** that can be delivered by a *data integration platform*? (i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

| | Very desirable | Desirable | Neutral | Undesirable | Very undesirable |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| My municipality can share its flood modelling data and/or raise awareness of its existence to the insurance industry (e.g., LiDAR data, flood protections) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Insurance companies can use the data my municipality shares when assessing property-level flood risks | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Year after year, my municipality can see how many properties are insured for flood | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| My municipality can see, year after year, how flood insurance prices are changing | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| My municipality can see the location of high-risk areas that insurance companies have identified | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| My municipality can see how its progress in flood risk management compares to other municipalities | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Upper levels of government can see the actions being taken by my municipality to manage local flood risks



Q18. Are there other functionalities of interest that can be delivered by a *data integration platform*? (i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

Q19. How likely is your municipality to use a *data integration platform* that has functionalities of interest for its flood risk management efforts?
(i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

- Extremely likely
- Likely
- Neutral
- Unlikely
- Extremely unlikely

Q20. Are there foreseeable **benefits** of a *data integration platform* for your municipality's flood risk management efforts?
(i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

Q21. Are there foreseeable **drawbacks** of a *data integration platform* for your municipality's flood risk management efforts?
(i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

Q22. Other comments or suggestions for research direction:

2. Survey for insurance companies (Survey Instrument #2)

Q1. Does your company sell residential flood insurance products in Canada?
(i.e., insurance coverage for property damages caused by rivers, rainfall and/or groundwater)

- Yes
- No
- I prefer not to answer

Q2. In which provinces or territories does your company offer residential flood insurance products?
(i.e., insurance coverage for property damages caused by rivers, rainfall and/or groundwater)

Check all that apply.

- Alberta
- British Columbia
- Manitoba
- New Brunswick
- Newfoundland and Labrador
- Nova Scotia
- Ontario
- Prince Edward Island
- Quebec
- Saskatchewan
- Northwest Territories

- Nunavut
- Yukon
- I prefer not to answer

Q3. Does your company offer flood insurance coverage to residential properties in these cities?
(i.e., insurance coverage for property damages caused by rivers, rainfall and/or groundwater)

Check all that apply.

- Toronto, Ontario
- Richmond, British Columbia
- Calgary, Alberta
- Halifax, Nova Scotia
- None of the above
- I prefer not to answer

Q4. Which factors can affect a property's residential flood insurance premium determined by your company?

(e.g., premium rate setting)

Check all that apply.

- Proximity to a river or waterbody (e.g., 100m distance from a river)
- Past flood-related claims
- The likelihood of flooding at the property
- The expected *depth* of flood waters
- The expected *velocity* of flood waters
- The expected cost of flood damages
- Local terrain characteristics
- Other: _____
- I prefer not to answer

Q5. Which factors might prevent your company from insuring a residential property for flood damages?
(e.g., refusing to issue flood insurance coverage to an applicant)

Check all that apply.

- Proximity to a river or waterbody (e.g., 100m distance from a river)
- Past flood-related claims
- The likelihood of flooding at the property
- The expected *depth* of flood waters
- The expected *velocity* of flood waters
- The expected cost of flood damages
- Local terrain characteristics
- Other: _____
- I prefer not to answer

Q6. Has your company identified specific areas or properties to which it would not make residential flood insurance available?

(i.e., properties at high risk of flood)

- Yes
- No
- Other: _____
- I prefer not to answer

Q7. Does this information play a role in determining where your company does not offer residential flood insurance coverage?

- The location of the property relative to a river or waterbody (e.g., 100m distance from a river)
- Third-party flood modelling/risk assessments (e.g., JBA, Impact Forecasting)
- Internal flood modelling/risk assessments
- History of flood damages of the property's surrounding community or municipality
- History of flood damages experienced by the property
- Presence of combined sewer systems in the property's neighborhood
- Other: _____
- I prefer not to answer

Q8. Would your company be willing to share the following information with government officials?
(e.g., municipal government officials)

Check all that apply.

- Properties that my company will not insure for flood damages
- Properties that my company has assessed to be at high-risk of flooding
- Postal codes/neighborhoods that my company will not insure for flood damages
- Data on uptake of flood insurance coverage (e.g., statistics on policies that are insured for flood damages)
- Spatial data my company has access to (e.g., flood hazard zones)
- Other: _____
- I prefer not to answer

Q9. If a residential property is considered at high-risk of flooding, how does its insurance policy and premium differ from properties at lower risk of flooding?

- Premiums are higher to reflect higher flood risks
- Deductibles are higher
- The maximum payout for flood damages is capped (e.g., \$10,000 maximum payout)
- Flood insurance coverage is not offered by my company to high-risk properties
- Other: _____
- There are no differences
- I prefer not to answer

Q10. How often does your company re-assess flood insurance premiums for policyholders?

- Never
- Every other year
- Annually
- Bi-annually
- Quarterly
- Other: _____
- I prefer not to answer

Q11. Which factors could trigger a re-assessment of flood insurance premiums for a policyholder?

- Upgrades to flood protections in the vicinity of the property (e.g., sewer upgrades)
- Upgrades to flood protections inside the property (e.g., sump pump)
- Updates in third-party flood models/property-level risk assessments (e.g., JBA, Impact Forecasting)
- Updates in internal flood models/property-level risk assessments
- Availability of new government data used for flood modelling (e.g., LiDAR topography data)
- Recent claims history of the policyholder (e.g., over the past couple of years)
- Other: _____
- I prefer not to answer

Q12. How often are **property-level** flood protections considered in business decisions regarding flood insurance (e.g., premium rate setting)?

Such as: sump pump installations, weeping tile systems

- Never
- Rarely
- Sometimes
- Often
- Always
- Other: _____
- I prefer not to answer

Q13. How often are **community-level** flood protections considered in business decisions regarding flood insurance (e.g., premium rate setting)?

Such as: dikes, dams, stormwater management infrastructure

- Never
- Rarely
- Sometimes
- Often
- Always
- Other: _____
- I prefer not to answer

Q14. How confident is your company that flood insurance products offered are accurately priced?
(e.g., confidence in the models used for pricing flood insurance products)

- Not at all confident
- Slightly confident
- Somewhat confident
- Moderately confident
- Extremely confident
- Other: _____
- I prefer not to answer

Q15. Would access to the following datasets improve your company's ability to assess flood risks?
(e.g., calibrating flood models, assessing property-level flood risk, calculating flood insurance premiums,
reducing uncertainty in your company's understanding of flood risk)

Check all that apply.

- Topography data (e.g., LiDAR Digital Elevation Models)
- Historical river gauge records
- Historical rainfall records
- Historical tidal gauge records
- Places where flooding has occurred in the past (e.g., spatial extent of historical floods)
- Places that are regulated/designated government floodplains (e.g., spatial extent of regulatory flood)
- Places that are protected from flooding (e.g., due to levees)
- Characteristics of flood defences, such as dams and levees (e.g., age, state of repair/maintenance)
- Properties that are flood-proofed because of government floodplain regulations (e.g., properties with raised foundations)
- Properties that have been part of government flood-proofing programs (e.g., sump pump subsidy programs)
- Other related data: _____
- None of the above
- I prefer not to answer

Q16. Are there other data or information that would improve your company's ability to assess flood risks? (e.g., calibrating flood models, assessing property-level flood risk, calculating flood insurance premiums, reducing uncertainty in your company's understanding of flood risk)

Q17a. The University of Waterloo researchers are designing and developing a user interface that displays government and insurance flood risk data and facilitates the exchange of data between agencies.

The remaining survey questions ask about the functionalities that could be delivered by this prototype (i.e., *data integration platform*) and that may be of interest to your company.

Q17b. Would your company be interested in these **functionalities** that can be delivered by a *data integration platform*? (i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

| | Very desirable | Desirable | Neutral | Undesirable | Very undesirable |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| My company can share information with governments about areas and properties at high risk of flood | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| My company can share information with governments about historical water damage claims | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Year after year, my company can see where flood protection upgrades have been made | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Year after year, my company can see which properties have participated in government flood-proofing programs | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| My company can receive updates about new flood model data created by governments (e.g., LiDAR topography data) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| My company can see industry-wide statistics on the number of insured properties for flood damages | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

My company
can see
industry-wide
statistics on the
number of high-
risk, uninsurable
properties



Q18. If this *data integration platform* were to exist, do you foresee it having an impact on the following: (i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

| | Very probable | Somewhat probable | Neutral | Somewhat improbable | Very improbable |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Increase flood insurance premiums offered by your company | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Decrease flood insurance premiums offered by your company | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Change where your company offers flood insurance (e.g., high-risk postal codes) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Increase confidence in your company's flood risk assessments | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Increase understanding of areas protected from flooding (e.g., due to flood protection infrastructure) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Promote fair competition between insurance companies | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Create efficiencies in the evaluation of flood risks conducted by your company | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Align public and private efforts in managing the flood insurance gap in Canada | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Q19. If this *data integration platform* were to exist, what foreseeable **benefits** are there for your company?

(i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

Q20. If this *data integration platform* were to exist, what foreseeable **benefits** are there for governments who share their data with the insurance industry?

(i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

Q21. If this *data integration platform* were to exist, what foreseeable **drawbacks** are there for your company?

(i.e., a platform designed to manage and visualize flood risk data owned by a range of public and private organizations)

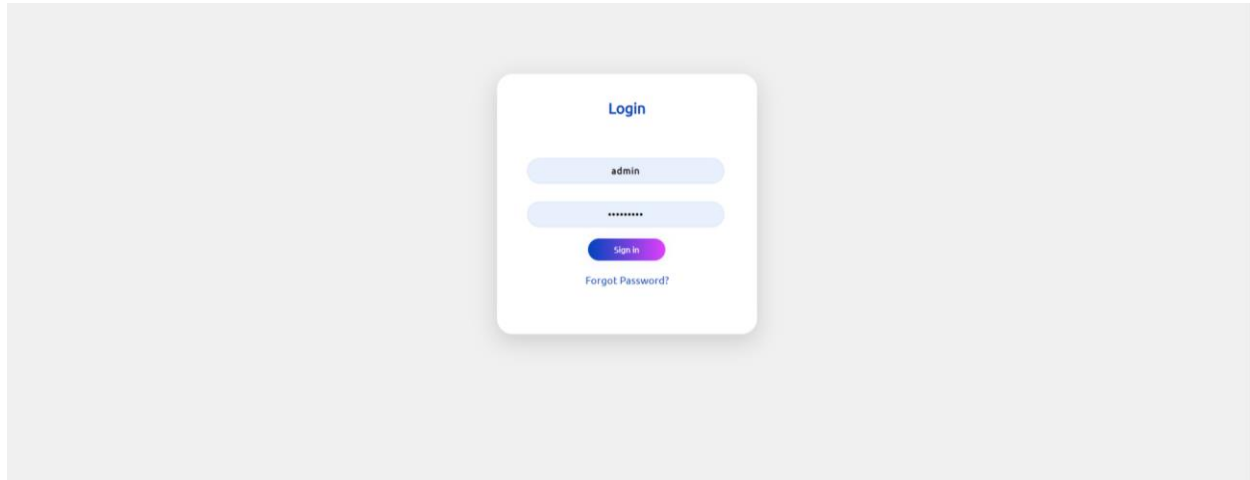
Q22. Other comments or suggestions for research direction:

Appendix C

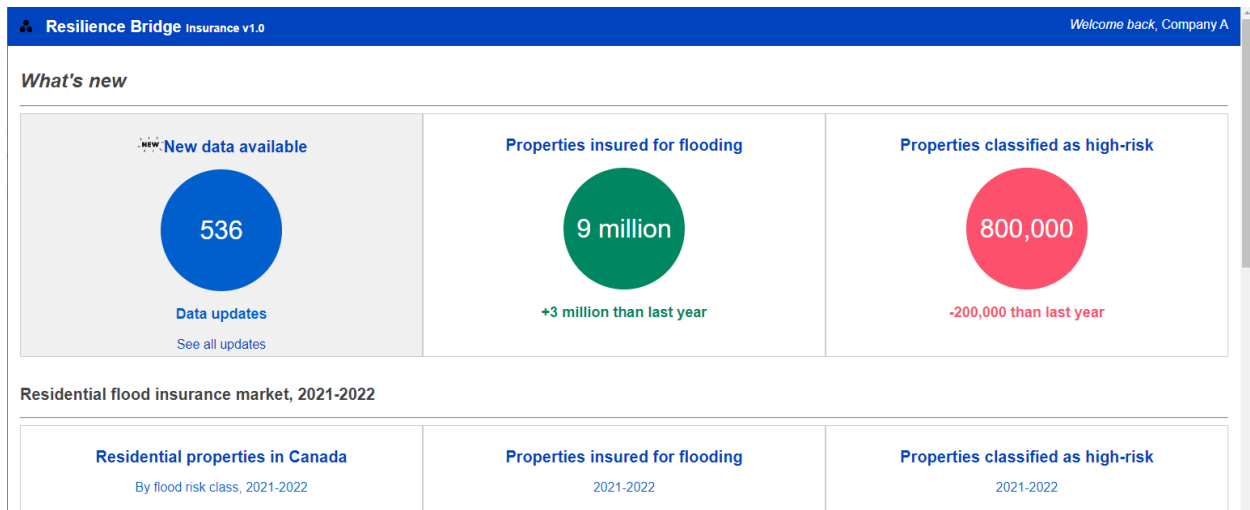
Resilience Bridge Platform Screenshots

Data platform for insurance companies (Interface #1)

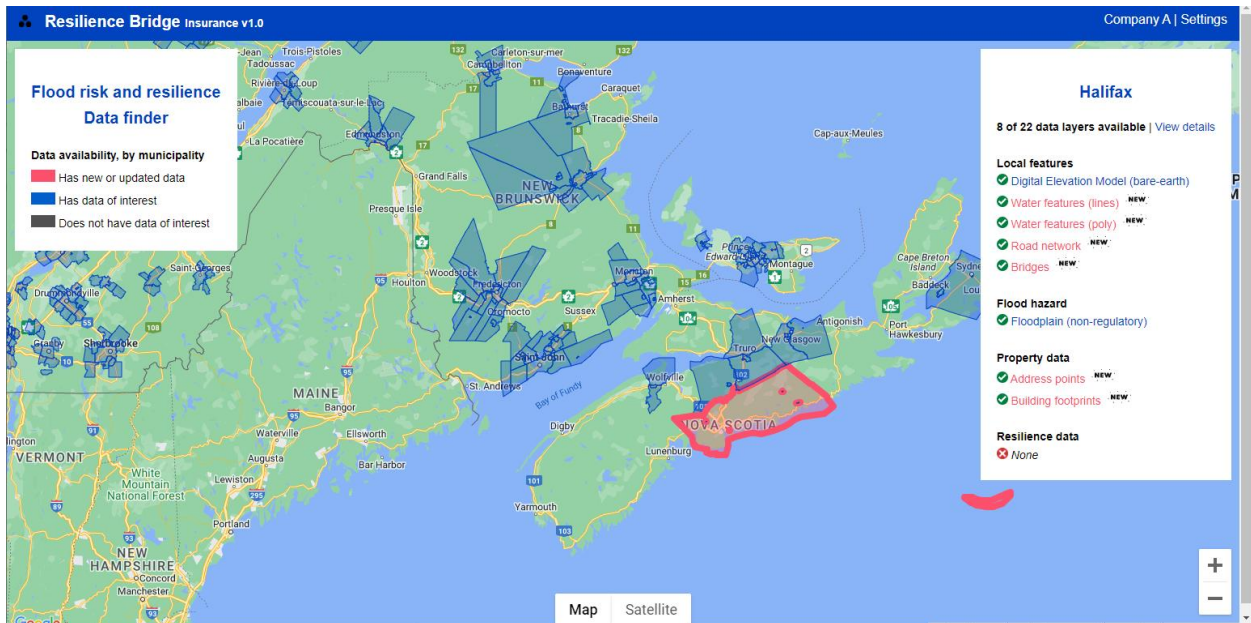
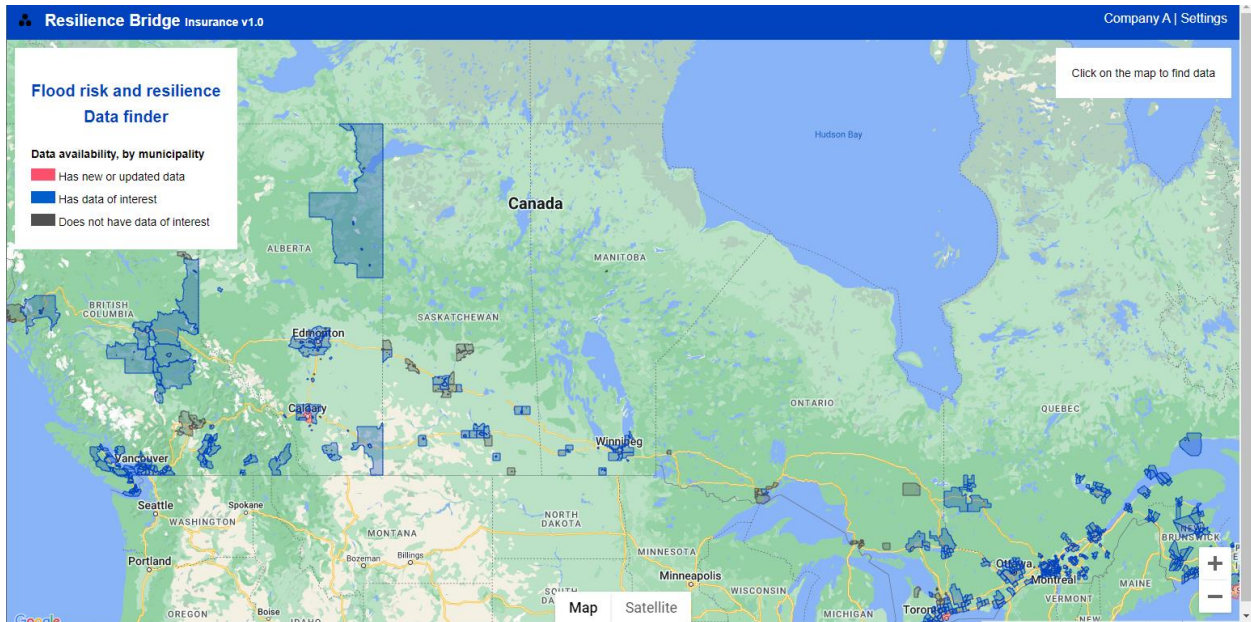
Login screen



Welcome dashboard with statistics about the flood insurance market



National data index for insurers to find government datasets



Data available for a particular city (this list is only for demonstration purposes, not exhaustive nor accurate)

Resilience Bridge Insurance v1.0
Company A | Settings

Halifax, Nova Scotia

6

new or updated data layers

8

data layers available

Overview of available data

| Local features (5) | Flood hazard (1) | Property data (2) | Resilience data (0) |
|--|---|--|--|
| <ul style="list-style-type: none"> Digital Elevation Model (bare-earth) ✓ Water features (lines) ✓ NEW Water features (poly) ✓ NEW Road network ✓ NEW Bridges ✓ NEW Railways ✗ Aerial photography ✗ | <ul style="list-style-type: none"> Regulated floodplain ✗ Floodplain (non-regulatory) ✓ River cross-sections ✗ Historical flood locations ✗ River gauge records ✗ Rainfall records ✗ Tidal gauge records ✗ | <ul style="list-style-type: none"> Address points ✓ NEW Building footprints ✓ NEW Property parcels ✗ Lot-level flood-proofing measures ✗ | <p>River and Coastal Flood Protections</p> <ul style="list-style-type: none"> Flood defences (e.g., dikes, dams, weirs, flood walls) ✗ Areas protected by flood defences ✗ <p>Stormwater Flood Protections</p> <ul style="list-style-type: none"> Storm sewer network (e.g., pumps, culverts) ✗ Areas protected by stormwater infrastructure ✗ |

Data preview

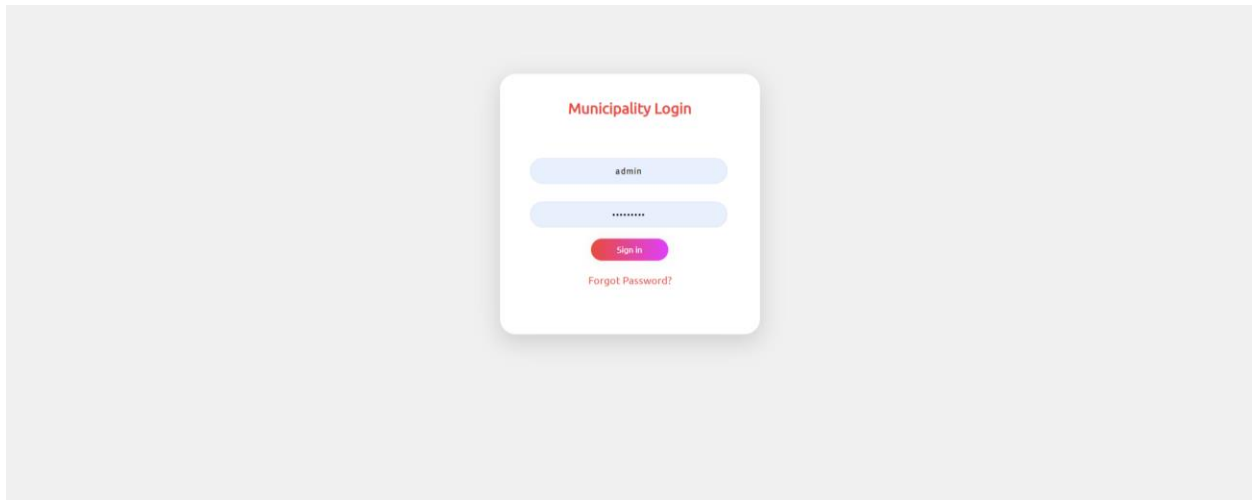
More details

| Name | Last updated | Download | Preview | Metadata | Data quality |
|--------------------------------------|--------------|----------|---------|----------|--------------|
| Digital Elevation Model (bare-earth) | 2018 | ↓ | N/A | Metadata | 🏆 |
| Water features (lines) | 2022 | ↓ | Preview | Metadata | 🏆 |
| Water features (poly) | 2022 | ↓ | Preview | Metadata | 🏆 |
| Road network | 2022 | ↓ | Preview | Metadata | 🏆 |
| Bridges | 2022 | ↓ | Preview | Metadata | 🏆 |
| Floodplain (non-regulatory) | 2019 | ↓ | Preview | Metadata | 🏆 |
| Address points | 2022 | ↓ | Preview | Metadata | 🏆 |
| Building footprints | 2022 | ↓ | Preview | Metadata | 🏆 |

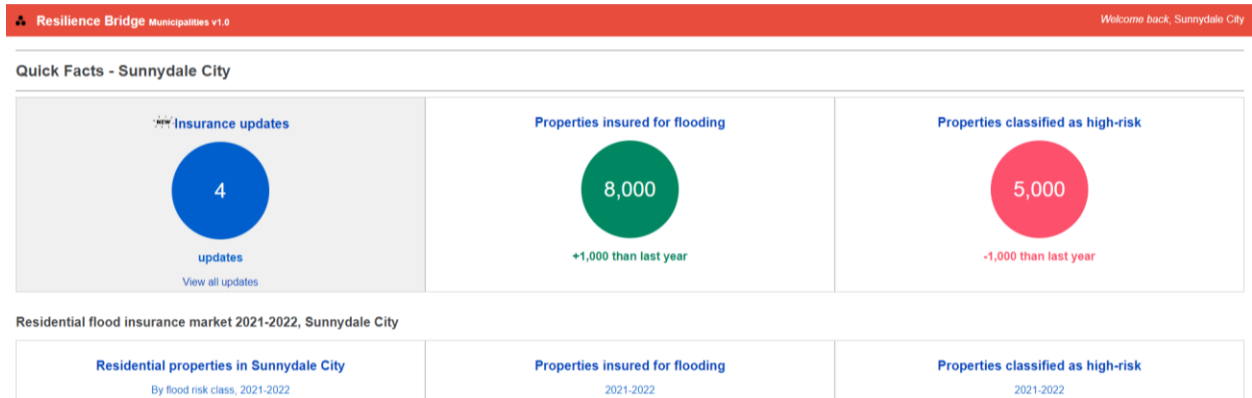
🏆 High quality 🏆 Medium quality 🏆 Low quality
 **Based on data completeness across the entire municipality, data currency, and whether data layer meets or exceeds data standards outlined in the Federal Floodplain Mapping Guidelines

Data platform for municipalities (Interface #2)

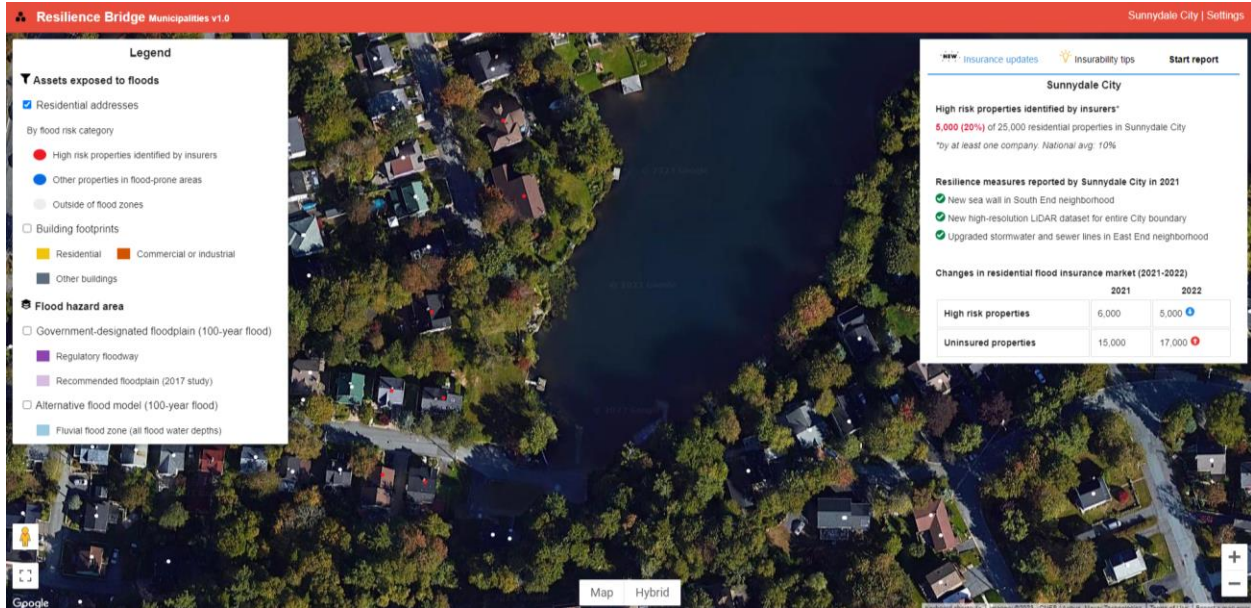
Login screen



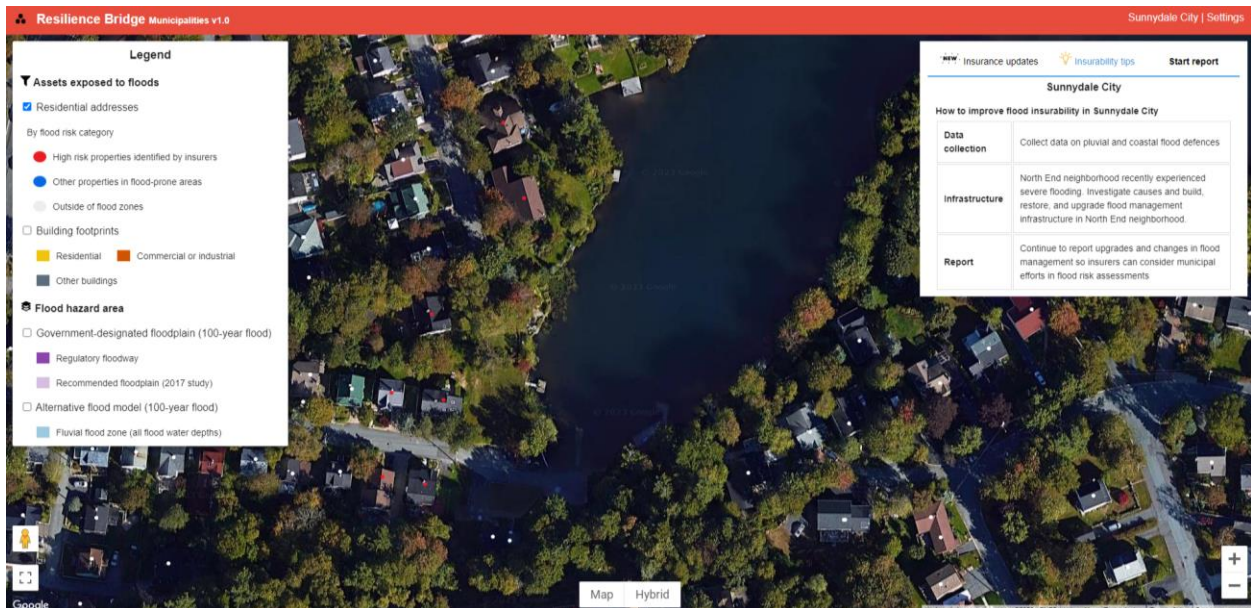
Welcome dashboard with statistics for Sunnydale City



Map viewer for Sunnydale City (high-risk properties are highlighted with red dots, this is only for demonstration purposes and not accurate nor exhaustive).




Insurability tips for Sunnydale City (this was meant to act as tips that insurance companies could provide municipal officials)



Reporting back tool (this was meant for municipal officials to upload new/changes to flood defences data)

2022 Flood Resilience Report - Sunnydale City

andrea.minano@gmail.com [Switch account](#) 

The name and photo associated with your Google account will be recorded when you upload files and submit this form. Your email is not part of your response.

Report instructions


Complete this report to share updates on Sunnydale City's flood resiliency efforts over the past year (Dec. 2021 to Dec. 2022). E.g., new data collected, new infrastructure built, upgraded infrastructure.

Insurability Tips:

Data collection
Collect data on pluvial and coastal flood defences

Infrastructure
North End neighborhood recently experienced severe flooding. Investigate causes and build, restore, and upgrade flood management infrastructure in North End neighborhood.

Report
Continue to report upgrades and changes in flood management so insurers can consider



Appendix D

Interview protocol for municipal officials

1. Welcome – turn on recording if they have accepted on the Consent Form

- The purpose of this meeting is to give you an overview of the tool that you will be evaluating
- Follow up from the surveys that were administered in 2021 and early 2022 for my doctoral studies. The surveys were completed by reps from 59 Canadian cities and 7 insurance companies that offer residential flood insurance
- My PhD research seeks to understand how public-private data-sharing could play a role in flood risk management in Canada, and the tools that could facilitate data-sharing across sectors
- Before doing the demo, I would like to start with some introductions, learn a little bit more about yourself if that's ok

2. Questions

2.1 Introduction

- Please introduce yourself + your role at [municipality]
- Are floods a problem for your municipality? Do you think your municipality is well-equipped to deal with floods? (e.g., capacity issues?)
- How do you come up with projects and priorities for municipal flood management? How do you currently evaluate progress? Reporting structure/tracking progress?
 - Is this an annual plan? Have you experienced bottle necks when implementing those plans? How have you overcome those bottle necks?
 - **When infrastructure upgrades are completed, are data technicians collecting data about these upgrades?**
- To your knowledge, have residents in your municipality faced issues with flood insurance? If so, how has your municipality responded to this resident concern?
 - **To your knowledge, have the action taken by your municipality changed flood premiums/risk categorization?**
- Does your municipality have access to data/information about flood insurance? Could you describe what this data looks like?
 - How did you get access to this information? What are you using it for? Is this static information or do you receive updates? Why did you seek this information? How reliable is this information?
 - **Has this insurance information informed municipal decision-making?** If so, how?
 - Has access to this information helped you build a case around infrastructure proposals?

- Has access to this information helped fund infrastructure projects? E.g., from the federal government, council
- Has this information informed land use planning? Why or why not?
- How often do you interact with insurance companies? **Insurance brokers?**
 - Do you communicate with insurance companies about updates/changes in municipal flood management? Why or why not? How does this process look like?
 - Do you share data with insurance companies? (e.g., hazard, property, resilience data)
 - What comes to mind when you think of “data-sharing”?

2.2 Demo walkthrough + discussion

- From the survey responses, it appears that municipalities and insurers in Canada are working in independent silos with little to no opportunities for interaction and for sharing resources, but an interest in accessing data that the other sector has
- for example only 6 municipalities of 59 reported having access to any information about flood insurance in their cities, but most were interested in seeing high-risk areas that insurers had identified
- Resilience Bridge Platform/intermediary, data collector/aggregator
- There may be an opportunity to establish a mechanism that could help information and communication flow between insurance companies and municipalities
- Insurance companies can share data on high-risk properties for municipalities to see
- Municipalities can share data on building footprints, stormwater management infrastructure, one stop for insurers to find govt data
- Receive updates on an ongoing basis, e.g., every year, monitoring the evolving nature of flood risks and the flood insurance market in Canada

What does this mean for a user in a municipality? As a user, Resilience Bridge would be a Web interface

Get your feedback on the ideas proposed, what is useful for you, not useful, early stages so this is an exercise for learning and evaluation

Questions or comments so far before we dive into demo?

2.2.1 Resilience Bridge – Interface #2

First impressions, how does this differ from what you already have

1. How would you/your team use an interactive map showing areas and properties that insurance companies have identified as high-risk of flooding/where they may not make flood insurance available?

- Realistically, **what is the level of detail that could inform decisions?** Property-level (like the example shown), or would neighborhood-level map suffice, or high-level statistics for your municipality? Is a report?
 - Are there drawbacks to getting access to this information?
2. On day-to-day operations, how would such a map be used by your municipality? By whom and in what context?
 - Who is the person that would use this information?
 - At what point in time would such a map be used by you?
 - **How would this be different from the information that you already have access to?**
 - Do you think this information could inform your flood management decisions? **Be an effective source of information to get projects funded?** Why or why not? DMAF application/making a case/priority-setting for infrastructure projects
 3. What could a Data Platform do to address limitations or capacity issues facing your municipality?

Alternatively, you can receive a report every year. Is there an advantage to an interface vs. a report?

4. The Data Platform can provide metrics for monitoring changes in flood risk and risk management in a municipality (e.g., number of high-risk uninsurable properties in 2022) and for comparing with other municipalities in Canada.
 - In your experience, could these types of metrics be used to access funds for flood management infrastructure projects? Do you foresee other uses for these metrics?
5. Should upper levels of government get access to this type of information about your city?

2.2.2 Resilience Bridge – Interface #1

6. The Data Platform could facilitate a process where periodically municipalities share updates with insurers (e.g., flood protection infrastructure built/upgraded in 2022) to produce a national index of available government data (e.g., hazard, property, resilience)
 - As a municipal official, are you interested in sharing municipal data with insurance companies for informing their flood risk analyses? Why or why not? Would this work be done by you or another department?

Few municipalities reported having data on flood protections

Sewer lines, attributes information for segments (e.g., a pipe's age of construction, date when it was last maintained), areas that are benefited by the defence and the level of defence

- Flood Protection Data Layer? (f/p/c)
- 7. Does your municipality currently collect that type of data? Or would it need to be digitized? Is it publicly available? Internal? Would you be inclined to share data on flood protections with insurance companies? Why or why not?
 - a. Do you have technical staff that keep these datasets up-to-date?
 - b. Is your municipality willing to periodically upload data to the Data Platform on Flood Protections?
- 8. What outcome would you like to see in return of your data contribution?

2.2.3 Outcomes

- To what degree, do you think the Resilience Bridge Platform can effectively produce the following outcomes? (e.g., 1 to 5=highly likely)
 - Improve access to decision-useful flood information
 - Incentivize governments to continuously work towards flood damage prevention
 - Increase your municipality's capacity to manage flood risks
 - Produce benefits for the public
 - Increase trust in insurance companies

2.3 Closing thoughts

- From what you've seen of Resilience Bridge, what is of most interest to you? What is of least interest?
- Who in your organization could be a user of Resilience Bridge?
- Who else in your organization might be interested in discussing Resilience Bridge?
- If Resilience Bridge was available tomorrow, what would change for your organization?
- Ideas for future iterations, maybe a completely different solution?
- Are there better ways of achieving the same outcomes?
- Why do you think this solution does not exist?

Other solutions of present challenges/concerns? Is this an adequate tool for overcoming challenges facing your municipality? Or are there other approaches that we have not discussed?

Involvement of upper tier governments?

An area where infrastructure has recently been upgraded, and supporting data/docs

Third-party?

Interview protocol for insurance representatives

1. Welcome – turn on recording if they have accepted on the Consent Form

- The purpose of this meeting is to give you an overview of the tool that you will be evaluating
- Follow up from the surveys that were administered in 2021 and early 2022 for my doctoral studies. The surveys were completed by reps from 59 Canadian cities and 7 insurance companies that offer residential flood insurance
- My PhD research seeks to understand how public-private data-sharing could play a role in flood risk management in Canada, and the tools that could facilitate data-sharing across sectors
- Before doing the demo, I would like to start with some introductions, learn a little bit more about yourself if that's ok

2. Questions

2.1 Introduction

- Please introduce yourself + your role at [company], how data plays a role in residential flood insurance products offered by your company?
- **Do you do your flood modelling in-house?**
 - Do you/your team actively seek out data for flood modelling or build upon third-party models?
 - Tell me about that process...are there pain points? What are you doing to address those pain points?
- How easy has it been to find data needed for flood risk assessments conducted by your company? (e.g., flood hazards, buildings, resilience measures)
 - Are there specific datasets that have been difficult to find?
 - In your opinion, what would make that process easier?
- How do you currently keep track of where upgrades in flood protection are happening across Canada?
- Has your company identified properties at high-risk of flooding (e.g., declined flood insurance coverage). Could you tell me a little bit about that process of identifying these properties? Would you be inclined to share data on high-risk properties with governments?

- Have there been instances in the past where properties that were previously identified as high-risk were reclassified to a lower risk category?
- Do you currently have access to industry-wide statistics on number of insured properties + number of high-risk uninsurable properties? Is that something that could be of interest, why or why not?

2.2 Demo walkthrough + discussion

- From the survey responses, it appears that municipalities and insurers in Canada are working in independent silos with little to no opportunities for interaction and for sharing resources, but an interest in accessing data that the other sector has
- for example only 6 municipalities of 59 reported having access to any information about flood insurance in their cities, but most were interested in seeing high-risk areas that insurers had identified
- Resilience Bridge Platform/intermediary, data collector/aggregator
- There may be an opportunity to establish a mechanism that could help information and communication flow between insurance companies and municipalities
- Insurance companies can share data on high-risk properties for municipalities to see
- Municipalities can share data on building footprints, stormwater management infrastructure, one stop for insurers to find govt data
- Receive updates on an ongoing basis, e.g., every year, monitoring the evolving nature of flood risks and the flood insurance market in Canada

What does this mean for a user in the insurance industry? As a user, Resilience Bridge would be a Web interface

Get your feedback on the ideas proposed, what is useful for you, not useful, early stages so this is an exercise for learning and evaluation

Questions or comments so far before we dive into demo?

2.2.1 Resilience Bridge – Interface #1 questions

Open data, or internal data that municipalities have

1. **How would your company use a Data Platform that displays a national index of available government data** (e.g., flood hazard, property, resilience data)? If so, how often would your company want to receive data updates?
 - a. Would it create efficiencies for your team/company? Benefits or drawbacks of the national data index? Who in your company could be a user of this Platform? How would they use it? When would they need the data? **What's missing?**

Few municipalities reported not having data on flood protections.

2. If the Data Platform asked government officials to upload data of flood protections, what should a Flood Protection Data Layer look like so that it can be used for insurance purposes? **(f/p/c)**
3. Asking local governments to partake in data collection could be challenging if there are no incentives to do so. Why should local governments invest time in creating and providing access to datasets of interest to insurers?

2.2.2 Resilience Bridge – Interface #2 questions

4. **Is your company willing to periodically upload data** to the Data Platform on where it does not offer flood insurance coverage/**consider to be high-risk of flooding for the use of government officials?** If yes or no, please explain.
 - a. What is your motivation to make your data available?
 - b. If I asked you for data for high-risk areas, would you make your data available via the Resilience Bridge platform? Why or why not? What assurances would you need to make your data available?
5. If government agencies took steps to physically reduce flood damages in high-risk areas your company has identified and reported these efforts via the Data Platform, how would that affect flood insurance availability and pricing?

2.2.3 Outcomes generated

- To what degree, do you think the Resilience Bridge Platform can effectively produce the following outcomes? (e.g., 1 to 5=highly likely)
 - Improve access to high-quality data used for flood risk detection and evaluation
 - Incentivize governments to continuously work towards flood damage prevention
 - Change where your company offers flood insurance (e.g., high-risk postal codes)
 - Change flood premiums offered by your company
 - Increase trust in government agencies

2.3 Closing thoughts (open ended)

- From what you've seen of Resilience Bridge, what is of most interest to you? What is of least interest?
- Who in your organization could be a user of Resilience Bridge?
- Who else in your organization might be interested in discussing Resilience Bridge?
- If Resilience Bridge was available tomorrow, what would change for your organization?
- Ideas for future iterations, maybe a completely different solution?

- Are there better ways of achieving the same outcomes?
- Why do you think this solution does not exist?

Glossary

| | |
|-----------------------------|--|
| Risk | “The combination of the chance of a particular event (such as a flood) occurring and the impact that the event would have if it occurred. Risk therefore has two components, probability and consequence. The consequence of an event may be either desirable or undesirable” (Sayers et al., 2013, p. 24). |
| Probability of flooding | “The chance of a particular part of the floodplain experiencing flooding after taking account of the performance of any associated flood control infrastructure (including both failure and nonfailure possibilities). The chance of flooding must be linked explicitly to an associated reference timescale (annual or lifetime probability for example) and specific characteristic(s) of the flood (depth, duration or velocity for example). The probability of flooding is not simply related to the return period of the driving storm” (Sayers et al., 2013, p. 24). |
| Uncertainty | “Any prediction/inference (timing of a storm, data, model or decision) that is not accompanied with complete sureness, whether or not described by a probability distribution. Uncertainty can be attributed to first, the inherent variability in natural properties and events (aleatory uncertainties), and second, incomplete knowledge of variables, parameters and model structures (both quantitative and qualitative models) (epistemic uncertainties)” (Sayers et al., 2013, p. 26). |
| Flood risk management (FRM) | “The process of data and information gathering, risk analysis and evaluation, appraisal of options, and making, implementing and reviewing decisions to reduce, control, accept or redistribute flood risks. It is a continuous process of analysis, adjustment and adaptation of policies and actions taken to reduce flood risk (including modifying the probability of flooding and its severity as well as the vulnerability and resilience of the receptors threatened). FRM is based on the recognition that risks cannot be removed entirely but only partially, and often at the expense of other societal goals.” (Sayers et al., 2013). |
| Flood risk governance | “The actor networks, rules, resources, discourses and multi-level coordination mechanisms through which FRM is pursued” (Alexander et al., 2016a, p. 39). “These [actors] are characterized by overlapping jurisdictions that do not match the traditional hierarchical order and multi-actor alliances that include traditional governmental actors such as the executive, legislative and judicial branch, but also socially relevant actors from civil society, most notably industry, science and non-governmental organizations (NGOs). This implicates an increasingly multilayered and diversified socio-political landscape in which a multitude of actors, their perceptions and evaluations draw on a diversity of knowledge and evidence claims, value commitments and political interests in order to influence processes of risk analysis, decision-making, and risk management” (Renn et al., 2011, p. 231). |
| Resilience | A multidimensional concept meaning “i) a measure of resistance (i.e. ability to block a disruptive event), ii) a measure of return to normality (i.e. recovery), iii) a measure of absorption and persistence, or as iv) a measure of adaptive capacity (including capabilities to learn and effect change)” (Alexander et al., 2016a, p. 40). |

| | |
|--------------------------|--|
| Effectiveness | <p>“The degree to which a measure causes risk to be reduced as expected or desired. In general the effectiveness of flood risk management as a whole is increased by adopting a portfolio approach, where the advantages of one option compensate for the disadvantages of another to minimize risk and maximize opportunities.” (Sayers et al., 2013, p. 22). Other schools of thought also posit effectiveness as the degree to which <i>legitimacy</i> and <i>resource efficiency</i> (i.e., time, money, effort) is achieved by FRM processes and activities (Alexander et al., 2016a).</p> |
| Governance fragmentation | <p>“The situation in which a ‘governance architecture’ is not regulated or dominated by a single (international) regime, but instead is ‘marked by a patchwork of international [and domestic] institutions that are different in their character (organizations, regimes, and implicit norms), their constituencies (public and private), their spatial scope (from bilateral to global) and their subject-matter (from specific policy fields to universal concerns)’” (Gilissen et al., 2016, p. 14).</p> |
| Governance integration | <p>“The opposite of fragmentation” which can be achieved by “enhancing interconnectedness within fragmented FRM systems (ie creating or intensifying effective interrelations between relevant actors at relevant points within the system) benefits the effectiveness of FRM”. Such as by establishing <i>transfer</i> mechanisms (e.g., information transfer or exchange), <i>coordination</i> mechanisms (e.g., aligning policies pursued by two actors), and <i>cooperation</i> mechanisms (e.g., establishing joint policies) (Gilissen et al., 2016, pp. 14, 16).</p> |
| Uninsurable risk | <p>“Uninsurability occurs when a prospective policyholder cannot buy the coverage [he/she/they] reasonably needs to combat the adverse consequences of damage resulting from an uncertain occurrence. This can happen in three situations: (1) the insurance product cannot be made available, (2) the insurance product is available, but sufficient coverage cannot be obtained, (3) the insurance product is not affordable to certain groups because of its price. It is obvious that especially in the second and third situation the designation of ‘uninsurable’ depends on a number of subjective factors” (Holsboer, 1995, pp. 407–408)</p> |